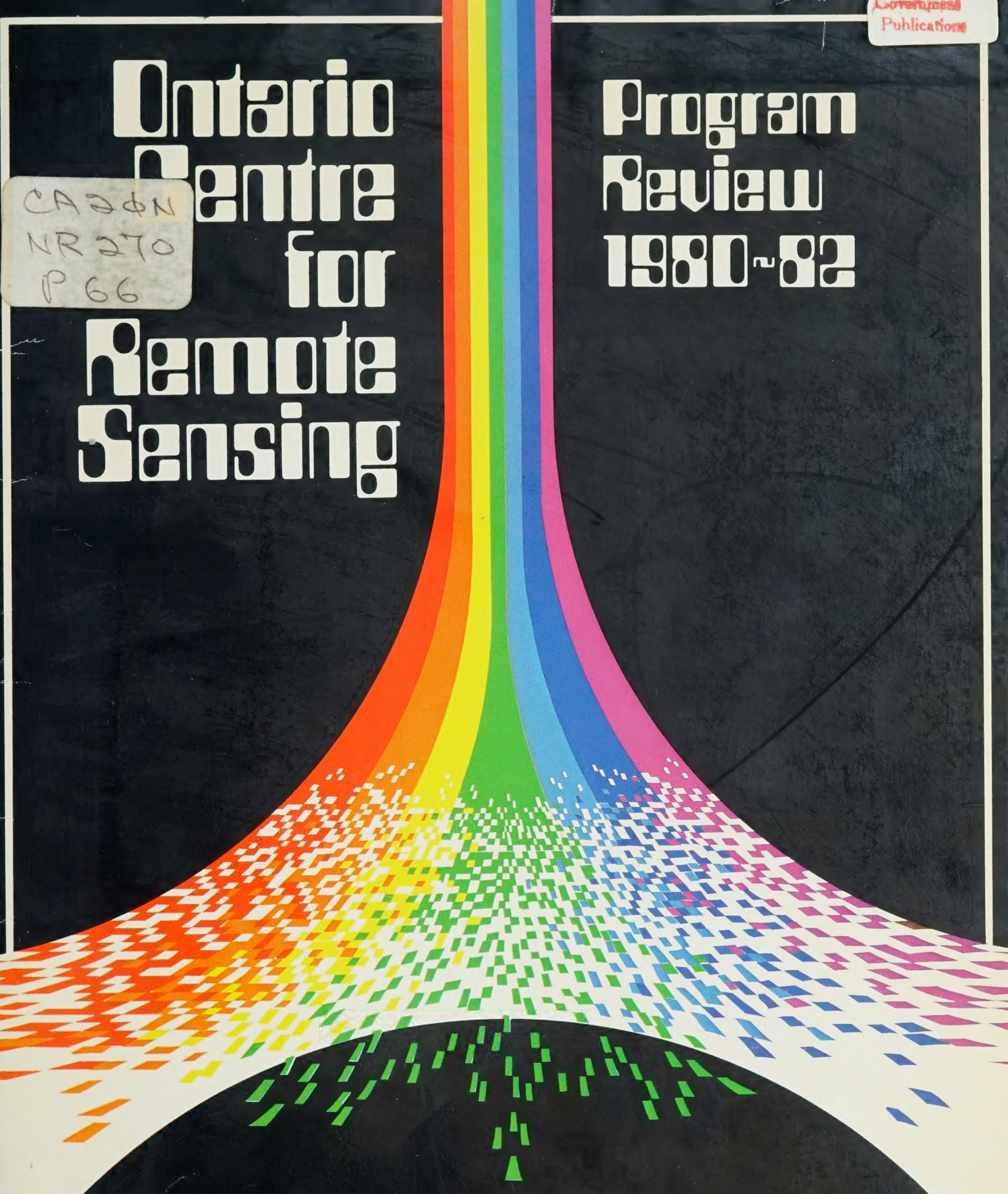
Ontario Centre for Remote Sensing

Program Review 1980~82



Ministry of Natural Resources
Ontario

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Hon. Alan W. Pope
Minister

W. T. Foster
Deputy Minister

ABSTRACT

The Ontario Centre for Remote Sensing (OCRS) is an organization established within the Government of Ontario to develop ways of applying remote sensing to the practical problems of resource management in the province, and to advance the operational use of remote sensing methods in the public and private sectors. This publication provides a review of the Centre's activities over the period 1980-82 in technological development, applied research, technology transfer and training.

FOREWORD

I am proud to present a summary of the Centre's progress in research and development over the past two years, particularly in the digital analysis of satellite data, but in airborne remote sensing as well. I am especially pleased to announce the development of a significant new computerized mapping system, which promises to remove an important barrier to the operational use of computer-classified satellite information. Another high point of this period has been the adoption of an OCRS-developed aerial photographic forest regeneration assessment methodology as an operational procedure by the Forest Resources Group of the Ministry of Natural Resources.

Through an active technology transfer program, the Centre has increasingly interacted with the private sector and educational institutions in Ontario. In 1982/83, the groundwork will be completed for a significant expansion of training and cooperation with private industry. The program is directed specifically toward digital image analysis and computer map production, which the Centre believes to be one of the most significant future directions in resource management.

I would like to express the profound gratitude of the OCRS to all those organizations, within the Ministry of Natural Resources and other ministries, and in the private sector as well, which had the foresight and initiative to give remote sensing a chance by sponsoring the Centre's work and collaborating with the Centre on research and trial-application projects.

The activities described in this report are attributed to the Centre as a whole, because one part of a team does not function independently. But this is not to diminish in any way the importance of the imagination, initiative, judgment and diligence of the individual OCRS scientist, without which the group would be nothing.

Inquiries for further information on any aspect of the projects described herein may be directed to myself or to Dr. Simsek Pala, Chief Scientist. We will be happy to reply ourselves, or to refer the inquiry to the OCRS scientist who was the principal investigator of the project.

VICTOR ZSILINSZKY
Associate Director
in charge of Ontario Centre for Remote Sensing

TABLE OF CONTENTS

LIST OF FIGURES

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TECHNOLOGICAL DEVELOPMENTS

INCREASED CAPABILITY OF THE DIGITAL IMAGE ANALYSIS SYSTEM

Demands on the OCRS digital image analysis system increased significantly over the period 1980-82. The initial stages of province-wide thematic mapping programs required continuous operation. In addition, access to the system was provided to scientists from government, industry and universities under the technology transfer program. The Centre's training seminars, as well, gave participants hands-on experience with digital image analysis.

To meet the increased demand, the OCRS purchased a second workstation, a Dipix Model LCT-11. It is now possible for two users to interact with the system at the same time to perform different image analysis tasks.

Major LANDSAT-based mapping programs also required an increase in storage capacity for the data generated by image analysis. The storage disk of the OCRS system permitted only one-eighth of a full LANDSAT frame to be analyzed at one time – an area equivalent to one 1:50,000-scale topographic map sheet. To analyze a 1:250,000-scale map sheet area required sixteen repetitions of the operation. Compared to the level of production of which the system was capable, this mode of operation was extremely inefficient for the mapping of large areas. To overcome this problem, the OCRS purchased and installed two large disks, each with a storage capacity of 200 megabytes, which permit a full LANDSAT frame to be analyzed at one step, at each of the two workstations.

The increase in system memory also made it possible for the Centre to conduct an intensive program of software development simultaneously with the mapping programs. One objective was to create programs which would electronically combine features drawn on a map with the results of the digital analysis of a LANDSAT image, so that a single map could be produced bearing the information from both sources. To be compatible with the LANDSAT-derived data, however, the features on the source map must be converted to digital data. To accomplish this conversion, the OCRS linked a Gentian Electronics Ltd. digitizing table to the image analysis system. When feature boundaries on a map are traced with a cursor, the digitizing table converts the coordinates to digital data and introduces them electronically into the LANDSAT analysis results, so that they appear as an outline on the monitor displaying the LANDSAT results. The data is thus integrated, ready for map production.

The second workstation, the significant increase in system memory and the digitizing table represent fundamental improvements in the OCRS image analysis system (Figure 1). The increased capability will broaden the scope and increase the effectiveness of the OCRS program to apply LANDSAT satellite data to resource management.

NEW COMPUTERIZED MAP PRODUCTION SYSTEM

The OCRS has developed the first operational system in Canada for the computerized production of maps directly from the digital analysis of LANDSAT data. The system is based on the Applicon Colour Plotter (Figure 2), a computerized printer which plots lines, curves and polygons at any selected scale on ordinary paper measuring 86 cm by 56 cm. Through the use of three ink jets, each applying a single basic colour, the plotter prints map features in up to 256 different shades of colour.

The OCRS designed software to convert digitally-classified LANDSAT data, geometrically corrected to the UTM grid, to a format acceptable to the Applicon system, so that digital analysis results could be immediately produced as a hard-copy map. (A range of 32 tones was found to be optimal for the colour-coding of map themes: if a greater number of colour levels are used, the differences among them are too subtle for the eye to distinguish consistently.) Together with Dipix Systems Ltd. of Ottawa and M. Murray TechniCom Consultants of Waterloo, the Centre developed programs to print a standard map format, complete with latitude and longitude references, UTM grid lines, a legend, the delineation of colour-coded themes in black or white, and the annotation of features with characters or symbols (Figure 3). Programs were also written to give scientists manual control over the outlining and colour-coding of special features by manipulation of a cursor on the image display monitor. This function has been used to depict on the final map certain known types of land use – urban development, parks or Indian reserves, for example – which are not distinguishable by spectral characteristics. Programs were also created to produce an electronic mosaic of the digital analysis results from two adjacent LANDSAT frames, in order to create continuity where the transition between images occurs within a single map.

Most recently, software has been developed to integrate digitized data from existing topographical, geological or other thematic maps with the LANDSAT analysis, and to produce colour-coded maps with the Applicon system from the combined data.

Once the digital analysis of an image is completed, it may take from one hour to one working day (depending on the size and complexity of an area) to prepare the digital analysis results for use on the Applicon system. The actual printing of the map is then completed within 15 minutes. The system can also produce colour separation masters (within one hour), for a significant reduction in the cost of map publication.

The computerized map production system makes resource information available to the user much more rapidly than could conventional mapping techniques, yet in a familiar, convenient format. No definitive comparison can yet be made between the

cost of operational LANDSAT-based mapping by this method and the cost of conventional mapping based on airphoto interpretation, field surveys, and manual map production. Results achieved to date, however, indicate that the saving will be dramatic. Another significant advantage over conventional mapping is the ability to update maps from the repetitive coverage of the satellite as changes occur, and thus to maintain greater accuracy. The development of the computerized map production technique, therefore, marks a transition between the research phase of the use of LANDSAT data and its readiness for operational application in resource management. Development of the capability to integrate digitized data from existing maps with the LANDSAT analysis is the first step toward the creation of computerized, geographically-indexed resource information systems with LANDSAT data as the base.

AERIAL PHOTOGRAPHIC CAPABILITY

The OCRS directed the development, by Syscomp Electronic Design Ltd. of Toronto, of an aircraft pitch and roll indicator and film annotation system, to provide more precise data on photo geometry for purposes of quantitative interpretation. This instrument, also known as a "tip/tilt recorder", measures the number of degrees of aircraft pitch and roll at a regular interval, and prints the data onto 70mm film through a Vinten camera system. The annotation display also receives an altitude reading from a foliage-penetrating radar altimeter. Each frame, therefore, bears information on the exact orientation of the aircraft at the moment of exposure. This information permits the photo to be geometrically corrected before measurements are made from it. Although acquired primarily for research into a methodology for aerial forest inventory sampling, the instrument represents a significant advance in the Centre's airborne sensing capability, as it provides for greater control over the quality of photogrammetric results.

AIRBORNE THERMAL SENSING

Aerial thermography research programs were advanced by the acquisition of a Daedalus Thermal Infrared Linescanner and data processor, with funding provided by the Ministry of Energy, primarily as a back up system for that Ministry's HEAT SAVE program of residential heat loss detection. The Centre also acquired the lease of a larger aircraft, a Navajo Chieftain, and outfitted it with two sensor hatches so that aerial thermography and photography could be acquired simultaneously (Figures 4, 5 and 6).

The Centre employs aerial thermography in a range of applied research projects; for example, in developing a technique to detect bedrock fractures from drainage and soil moisture patterns. The in-house capability for obtaining airborne thermal coverage permits the Centre to conduct more basic research into the thermal characteristics of natural and man-made features.

For the past four years, the OCRS has conducted research toward the establishment of a methodology based on the digital analysis of LANDSAT data for mapping general and agricultural land use, forest resources and northern wetlands over extensive areas of the province. A major result of this work is the development of a computerized map production system which adapts LANDSAT data to operational applications. Activities over the period 1980-82 in each field of application are outlined below.

LAND USE/LAND COVER MAPPING

In 1980/81, operational trials in land use/land cover mapping from the digital analysis of LANDSAT data were planned over sites representing different geographic regions of the province (Kingston, Timmins and White River). The Land Use Coordination Branch of the Ministry of Natural Resources specified map themes for each site, varying in number with the complexity of land use present to a maximum of 16. The operational inefficiency of the small storage disk of the digital analysis system first became evident in the course of this project. The disk could accommodate the analysis of only one 1:50,000-scale map sheet area (approximately one-twentieth of a LANDSAT frame); therefore, numerous repetitions of procedure would have been required to complete the planned test areas. While acquisition of a larger disk was in progress, the project was continued over smaller test sites, of which geometrically-corrected 1:50,000-scale colour maps were produced.

In 1981/82, using the larger disk, 1:250,000-scale land use/land cover maps were produced for the same three test areas. The LANDSAT images were classified into land use categories, then geometrically corrected to the UTM grid. Large cities were easily distinguished; in fact, the downtown core could in some cases be distinguished from the outer, industrial zone. Small towns, however, were often misclassified as part of the surrounding agricultural area. This source of error has largely been eliminated by newly-developed software which reproduces on the map an outline of the community drawn on the image-display monitor with a cursor, and shades it in the selected colour. The same software permits the tracing of the boundary of Indian reserves and parks. In agricultual areas, two seasons of imagery were needed to complete a relatively detailed level of classification – summer imagery for the identification of crop-covered areas, and spring imagery to distinguish crops from pasture land. The new software which integrates two LANDSAT analyses into the same map was developed in response to such a problem. Three major classes of woodland were mapped – predominantly coniferous, predominantly deciduous, and mixed forest. Cutover areas, burns and areas of forest regeneration were also classified in regions where they were considered a priority. The amount of detail that will be included within wetland areas will depend upon how prevalent the wetland features are in the landscape: they will be mapped in greatest diversity in the Hudson Bay-James Bay Lowland.

As required, information on the total area coverage of individual themes within selected UTM grid cells, map areas or full map sheets can be extracted from the LANDSAT analysis and printed out on the map legend.

In general, the objective was to achieve an accuracy greater than 80%. When the LANDSAT-derived maps were compared with the results of visual interpretation of LANDSAT imagery and of aerial photography, it was found that an accuracy of 90% had been achieved in mapping the general categories of forest land, agricultural land and waterbodies. Some classes within agricultural areas had an accuracy lower than 80%, because of the spectral confusion between pasture land and hay fields, and between uncultivated fields and urban development.

No systematic comparison could be made between the cost in time and money of the OCRS land use maps and the cost of land use maps produced by conventional methods, simply because no complete data on the cost of a conventional land use mapping program could be obtained. However, the following information is pertinent to such a comparison. For each 1:250,000-scale NTS map sheet covering 16,000 km^2, the Centre will produce one 1:250,000-scale and sixteen 1:50,000-scale maps. On the basis of experience to date, it is expected to take two persons one month (i.e. approximately 40 man-days) to produce these 17 maps, together with colour-separation masters, assuming that the computer system is dedicated full-time to this task. Excluding the cost of the equipment itself and development costs, the operating costs to perform this work, in addition to salaries, may be estimated at $10,000, including hardware and software maintenance, supplies and hardware depreciation. The cost of the 17 map sheets will, therefore, be in the order of $1.00 per square kilometer. Conventional land use mapping would require photography at a scale such as 1:50,000, as it would not be efficient to employ standard 1:15,840-scale aerial photography over a large region. It is estimated that the cost of obtaining this photography alone over a 16,000 km^2 area would equal the total cost of LANDSAT-based map production.

In addition to the major land use mapping program, the OCRS began to perform land-and-water area mapping and calculation by administrative district. This program will be extended across the province in 1983.

A meeting of Ministry of Natural Resources land use planners was held in November, 1981 at which the OCRS presented sample maps, described the classification and mapping technique, and invited comment on the classification system employed. The new maps were particularly welcomed by planners at the regional level.

Several other small projects have been requested as a result of interest in the sample maps; for example, a land use/land cover map of an area near Simcoe was undertaken for Ontario Hydro.

The LANDSAT-based land use mapping program will produce a new generation of land use/land cover maps. The ultimate objective of the program is to complete the mapping of land use across the entire province at scales of 1:250,000 and 1:50,000, with assistance from the private sector, which is expected to develop the capability to perform digital image analysis services in the near future.

MAPPING OF FOREST RESOURCES NORTH OF LATITUDE 52°N

No inventory of forest resources exists for the vast region of Ontario lying north of latitude 52°N. With the support of the Forest Resources Group of the Ministry of Natural Resources, the OCRS has begun a program to classify this forest region, for the first time, by the digital analysis of LANDSAT data, and to make the information available in the form of colour-coded maps produced by the Applicon Plotter. Although the level of detail which can be extracted from LANDSAT cannot be compared with the level of detail provided by the standard aerial photography-based inventory method, it is sufficient for the relatively broad classification required in this region. The present economic value of these forests does not warrant a more intensive study. Furthermore, forest conditions in the region are relatively simple: black spruce is by far the dominant species, with a much smaller proportion of jack pine, poplar and minor species. The fact that the majority of stands are homogeneous permits LANDSAT analysis to achieve a high degree of accuracy.

An area of 2000 km^2 was mapped in 1980/81, and a further 10,000 km^2 in 1981/82. Two seasons of imagery were required to complete a classification. On winter imagery, black spruce and jack pine can be distinguished, as well as dense and open conifer stands. On summer imagery, deciduous forest areas, wetlands, barren areas and waterbodies are more accurately mapped. Mixed forest and shrubs can best be distinguished by a comparison between the two seasons. A new program which combines the classification results of winter and summer imagery through logical operations has permitted considerable progress to be made in this project.

SELECTIVE FOREST TYPING

In cooperation with the Forest Research Branch of the Ministry of Natural Resources, the OCRS began in 1980/81 to map the occurrence of jack pine forests in selected areas of the province, using the digital analysis of LANDSAT data and the computerized map production technique. On some late winter images, a distinction could readily be made between jack pine and black spruce forests.

In 1981/82, eight 1:250,000-scale map sheets were completed for an area covering more than two LANDSAT frames. It was discovered that, although late winter imagery permitted jack pine to be isolated easily, jack pine could not be reliably distinguished from cedar on April and May imagery. Further research will be done to determine why this confusion occurs.

The purpose of the project is to provide data for tree-improvement research. If geographically distinct groupings of jack pine forest are found to exist, biochemical testing will be done to determine whether they are separate populations genetically. If that is the case, seed collection and planting by geographic region will be indicated for improved forest regeneration success.

The LANDSAT-based method is expected to accomplish the survey more efficiently than the best alternative method, the compilation of data from Forest Resources Inventory maps or aerial photography.

FOREST FUEL MAPPING

Work continued on the development of a practical procedure for the mapping of forest fire hazard classes, based on the digital analysis of LANDSAT data. The first stage of the mapping procedure is to perform the supervised classification of test areas according to themes relevant to forest value and inherent susceptibility to fire which are specified by the Forest Fire Management Centre of the Ministry of Natural Resources. For example, dense jack pine is distinguished from open jack pine, dense black spruce from open black spruce, open bog from treed bog and dense hardwood from mixed forest, because each species and condition represents a different level of readiness to burn. The resulting classification is then grouped by a second analysis into high, medium and low fire-hazard categories, as well as non-forest classes such as water, bogs, rock outcrops, and developed and agricultural areas.

Fuel mapping was completed for a test block lying in the Sault Ste. Marie and Blind River districts. Staff of these districts will evaluate the resulting Applicon-produced colour-coded map during the forest fire season of 1983. The fire-hazard maps are designed to assist the establishment of fire-fighting priorities and the planning of strategy, particularly in the case of large fires or the simultaneous outbreak of several fires.

MAPPING OF WETLANDS OF THE HUDSON BAY-JAMES BAY LOWLAND

In 1979/80, the OCRS completed a program of field sampling of wetlands in the Ontario portion of the Hudson Bay-James Bay Lowland to support the mapping of wetland types across this region from the digital analysis of LANDSAT data. Mapping was begun from the south in order to develop a basic wetland classification scheme in an area free of permafrost. From this part of the region, the first map in the series (Ghost River map sheet 42-0) was produced. The classification scheme will be adjusted to accommodate the effects of discontinuous permafrost as the mapping proceeds northward.

In 1981/82, software was developed to permit surficial geological features of the region, mapped from aerial photography and field survey in a separate OCRS program, to be combined with the LANDSAT-derived wetland classification. Software was also developed to integrate the analysis of two seasons of LANDSAT data; the comparison of different seasons produces more accurate results for certain wetland themes than can be achieved using data from a single season. Finally, software was produced to mosaic the digital analysis of two LANDSAT scenes electronically, where the transition from one frame to the next occurs within the same map sheet.

The Centre's objective is to produce maps for the entire region at a scale of 1:250,000, and to provide 1:100,000-scale maps, as required, for specific investigations. Now that all the required software has been developed and has proven satisfactory in trial runs, the Centre plans to complete ten map sheets before April, 1983.

The wetland classification maps will provide information for the first time on the actual extent of Ontario's peat resources, and will constitute a data base, including information on caribou and migratory bird habitat and on ecological characteristics of the wetlands, which can be used for planning the development of Ontario's far north.

SURFICIAL GEOLOGY MAPPING FOR NORTHERN ONTARIO

Manuscript surficial geology maps for a 500,000 km^2 region of Northern Ontario for which no comprehensive surficial geology data existed were completed in 1980. Existing 1:60,000-scale black and white airphotos, as well as LANDSAT satellite imagery, were used in selecting field investigation sites, in preliminary mapping, and in planning the logistics of the 1977 program of field sampling which used helicopter access to field investigation sites. Final mapping was performed by transfer of surficial geology features interpreted from airphoto stereopairs to airphoto mosaics.

The next step is the publication of 33 1:250,000-scale maps of surficial geology and wetlands, of which 15 maps in the Precambrian Uplands region contain surficial geology information alone. If traditional cartographic processes were used, the publication cost of the maps would be in the range of $800,000. In an effort to reduce both the time and expense required for publication, the OCRS developed a technique for printing the maps with the Applicon Colour Plotter.

The Centre acquired an X-Y digitizer, with which to convert manually-delineated surficial geology features to digital data for incorporation with the digital classification of LANDSAT data for waterbodies and wetlands. Programs have been prepared for the printing of geological map symbols simultaneously with the colour-coded map features.

Not only will the Applicon map production technique save time and money, but it will also allow for the reprinting of the data at any desired scale.

To accompany the maps, reports are being prepared which provide information on glacial history and physiography, and describe in detail the samples taken and observations made at each field investigation site.

MAPPING OF PEAT RESOURCES OVER THE PRECAMBRIAN SHIELD

In cooperation with the Ontario Geological Survey, the OCRS has begun to classify and map the wetlands of the Precambrian Shield region of Ontario, by the digital analysis of LANDSAT data and computerized map production.

In 1981/82, bogs were mapped over three sites, one west of Thunder Bay, one northwest of Timmins, and one north of Ignace. During the summer of 1982, intensive field sampling will be performed at selected wetland sites in order to develop an operational procedure for the measurement of peat depths and decomposition rates, from which peat volume and peat quality will be estimated. Once the distribution of wetlands is known and a method established for peat volume estimation, it will be possible to achieve a careful estimate of the total peat resources of the Precambrian Shield in Ontario.

AGRICULTURAL LAND USE MAPPING

In collaboration with the Food Land Development Branch of the Ministry of Agriculture and Food, the OCRS continued a program of research to develop a methodology for agricultural land use mapping based on the digital analysis of LANDSAT data. Finch Township in southeastern Ontario was chosen as the first test site. From spring imagery, eight agricultural land use classes were mapped (cultivated fields, cultivated fields containing drainage tiles, hay, pasture, deciduous and coniferous forest, waterbodies and urban development). Field data was gathered at selected sites by Ministry of Agriculture personnel. In 1981, the classification of a late summer image was completed for the recognition of types of annual crops, and an agricultural land cover map for Finch Township was produced using the Applicon Colour Plotter. This mapping is currently being extended over the remaining five townships located within the same LANDSAT frame. A second test has begun in Aldborough Township in Southwestern Ontario, which contains a greater diversity of crop types than Finch Township.

In recognition of the need for a back-up system to prevent a gap in LANDSAT coverage from disrupting an operational agricultural land use mapping program, the OCRS began to conduct tests to establish a supplementary aerial photographic or airborne video recording system for this purpose. Over Aldborough Township and the Alliston area of Ontario, black and white and colour video recordings were made at the same time as 35mm aerial photography was obtained using a Didec Research and Development Ltd. Enviropod camera mount. A report on the evaluation of this data will be produced in 1983.

The results of this program to date indicate that the major agricultural land cover classes specified by the Food Land Development Branch can be accurately mapped from digital LANDSAT data. The LANDSAT methodology, supplemented by airborne imaging, may offer a practical alternative to the conventional method of intensive field data collection.

VEGETATION CHANGE DETECTION

The digital analysis of two LANDSAT images obtained in the same month of 1973 and 1980, respectively, was performed using the unsupervised classification method, to detect changes in the extent of vegetation cover in the study area over the seven-year period which could be related to changes in industrial activity. Using mapping software developed during 1981/82, the two classifications were then combined, and three new themes mapped: areas of no change, areas of increased vegetation cover and areas of decreased vegatation cover. The Applicon-produced vegetation change map confirmed areas of suspected damage and of new growth. For areas of previously unsuspected vegetation change, on-site study will be required to determine the cause.

In 1982/83, the Centre will perform an analysis of vegetation for the same study area on LANDSAT data from 1976 and 1979, in order to trace the stages of development of the changes in growth, and to determine if a trend is still continuing.

The repetitive nature of LANDSAT coverage makes it particularly useful for historical comparison. This project developed a practical, automated methodology for the application of LANDSAT data to environmental monitoring.

DEER HABITAT MAPPING FROM LANDSAT IMAGERY

For the Fort Frances District of the Ministry of Natural Resources, the OCRS performed a digital analysis of LANDSAT data to determine those areas in the district most suitable for deer habitat.

The following themes were classified, to a minimum feature size of $500m^2$: forest types, wetlands, agricultural cropland, unimproved pasture and urban development. The analysis was completed for an area of eight 1:50,000-scale NTS map sheets, and maps of the results were produced with the Applicon system.

Wildlife biologists of the district were particularly interested in relatively open areas, areas of early successional deciduous forest which provide deer with winter browse, and areas of coniferous forest which provide winter shelter. They found the LANDSAT analysis a satisfactory source of information on the location, distribution and area coverage of these vegetation classes.

LANDSAT D AND SPOT SIMULATION EXPERIMENT

Under a program conducted by the Canada Centre for Remote Sensing (CCRS), the OCRS participated in an experiment to investigate the improvement over present capabilities that will be provided by the finer spatial resolution of the sensors aboard the LANDSAT D and SPOT satellites scheduled for launch in 1982 and 1984, respectively. CCRS obtained airborne multispectral scanner data which simulated the wavelength sensitivity and spatial resolution of LANDSAT D and SPOT. The OCRS digitally analyzed this data for types of land cover and agricultural land use. The spectral ranges and spatial resolution of both satellites were found to be excellent for the mapping of these features. It was not possible, however, to determine the effect on data quality of the orbital altitudes of the satellites; no conclusion could thus be drawn as to the precise degree of improvement which LANDSAT D and SPOT will provide.

INVESTIGATION OF REMOTE SENSING TECHNIQUES FOR WILD RICE INVENTORY

In cooperation with the Northwestern Regional Office of the Ministry of Natural Resources, the OCRS tested the capability of aerial photography, airborne colour video recording and the digital analysis of LANDSAT data to provide an alternative to the traditional aerial sketching technique for the inventory of wild rice beds in waterbodies. An attempt was made to delineate wild rice beds from each data type, and to distinguish dense from sparse growth. The test areas were located in the Kenora and Sioux Lookout Districts.

Three scales of photography and four film types were tested. The scale of 1:30,000 was found more favourable for wild rice mapping than the smaller scales of 1:50,000 and 1:70,000. The scale of 1:10,000 provided optimum detail, but was considered impractical for regional coverage. The colour infrared photography was found more informative than the true colour, black and white panchromatic and black and white infrared films.

Colour video recordings were made from three altitudes. The altitude of 3000 ft. (915mm) was found to be the best compromise between the need for detail to identify wild rice along streams and creeks and the need for a broad field of view for orientation and for surveying large lakes.

Digital analysis was performed on a LANDSAT image obtained in late July, at the peak of wild rice growth. The aerial sketching data available from the field, however, were insufficient for a well-controlled analysis. In some areas, it was not possible to determine whether the reflectance differences present resulted from differences in density of wild rice or from the presence of both wild rice and other aquatic vegetation. The wild rice areas identified on the aerial

sketching data were present on the digital classification as well; however, the digital classification identified other additional wild rice beds which must be verified.

It was concluded that all three types of remote sensing data were potentially useful for the inventory of wild rice. Colour infrared photography, however, was considered too expensive for regional application. Further research was recommended into the use of LANDSAT data and airborne video recording for this purpose, as each method would offer a significant cost advantage over aerial photography.

A remote sensing technique for wild rice inventory over a vast region would be more efficient and less costly than traditional aerial sketching and field survey methods, and would provide a permanent visual record for verification and reference.

STUDIES OF WEATHER SATELLITE DATA OF THE GREAT LAKES

OCRS scientists observed an anomaly consisting of a series of parallel bands on NOAA-6 satellite imagery of the Great Lakes. The feature appeared to travel quite rapidly through the Great Lakes system from Lake Superior to Lake Ontario. The usual explanation for this anomaly is sun-glint from the water. OCRS scientists, however, suspect that the cause may be a highly reflective substance at or beneath the water surface. Further investigations will be conducted using digital NOAA and GOES satellite imagery, to determine the rate of movement of the phenomenon and other relevant characteristics.

HEAT CAPACITY MAPPING MISSION STUDY

The Heat Capacity Mapping Mission (HCMM), a satellite launched in 1978, recorded imagery in the visible and thermal infrared spectral ranges from an altitude of 620 km. Using the Applicon system, the OCRS produced three experimental maps from thermal HCMM data obtained on June 16, 1978 over central Ontario and western Quebec. The first map indicated day-night thermal differences produced, for example, by differences in exposure of areas to sun or by topographic differences. Other maps represented thermal inertia, the measurement of the resistance of a material to the flow of thermal energy. Thermal inertia mapping is potentially useful to geological surveys and mapping.

To supply aerial photography suited to the diverse requirements of a large number of projects, the OCRS has developed a small-format aerial photographic system, controlled by a microcomputer, for simultaneous operation of up to four 70mm Hasselblad or Vinten or 35mm Nikon cameras.

The purchase of a Daedalus thermal line-scanner and image processor, as well as the lease of an aircraft which accommodates the aerial photographic system and the scanner simultaneously, significantly increased the versatility of this in-house resource. For projects which require complete coverage of large areas, either photographic or thermographic, the Centre contracts private companies to obtain the data.

The OCRS has developed practical applications of aerial photography to several fields, with particular emphasis on forest management. Aerial thermography was initially employed for surveys of heat loss from buildings; however, its use has been extended to water resources investigations, the detection of frost-prone areas as an aid to reforestation programs, and to aspects of geotechnical studies.

Using data provided by the RADARSAT Office of the Canada Centre for Remote Sensing, the OCRS has tested the capabilities of airborne radar sensing for forestry applications, vegetation analysis, land use mapping and geology.

The following is an outline of OCRS activities in all three forms of airborne sensing – photography, thermography and radar – from 1980 to 1982.

THE EVALUATION OF CONIFEROUS REGENERATION SUCCESS FROM COLOUR INFRARED AERIAL PHOTOGRAPHY

In cooperation with the Forest Resources Group of the Ministry of Natural Resources, the OCRS has developed an aerial photographic method for evaluating the success of coniferous forest regeneration in cutovers and burned areas, and is coordinating the operational use of the method by forest managers of the Ministry.

The technique is designed to provide the data normally gathered by an on-site survey five to seven years after seeding or planting, when black spruce has reached a minimum height of 0.8 m. Three scales are used, 1:20,000, 1:9,000 and 1:4,500, all studied stereoscopically. Prints are made only of the smallest scale; the other two scales are interpreted directly from the diapositive film rolls. The 1:20,000-scale prints are used to produce a base mosaic of the areas under study and to perform initial stratification according to relative density, stocking, height, age and physiographic features. Data on species composition and age are derived primarily from existing treatment records or from field observations. Stocking is the factor which determines the degree of regeneration success: areas with more than 70% stocking are considered successes, areas with 40% to 70% stocking partial successes, and areas with less than 40% stocking failures. Stocking is assessed from the 1:9,000-scale photography using a specially-designed template. Stand density is estimated from the largest scale of photography, 1:4,500, using another special template to outline the sample plot areas. Stocking and density comparators have also been designed, so that the forest manager may obtain a cursory and subjective estimate of stocking and approximate density conditions, when required, by visual comparison of the pattern of growth with samples of various levels of stocking and density.

Additional information on forest conditions such as insect damage and frost-kill can be extracted from the aerial photography. Patterns of scarification and planting which may be difficult to discern at ground level can also be detected to supplement existing treatment records.

In 1981/82, the OCRS coordinated the acquisition by Capital Air Surveys Ltd. of photography for regeneration assessment over sites selected by the Thunder Bay, Kapuskasing and Wawa District Offices, with a total area of over 123,000 hectares (307,000 acres). OCRS scientists gave one week of instruction in the use of the assessment method to foresters and forest technicians at each district. The field offices then performed an operational assessment of the areas for which photo coverage had been obtained.

The results achieved by the field offices demonstrated the practical value of the new method. Spruce Falls Pulp and Paper Co. Ltd., which completed a large part of the assessment for Kapuskasing District, documented an accuracy of 85% to 90%, and reported that the cost of the operation was one-quarter the cost of the traditional field survey operation. Wawa District reported that the assessment cost was $1.14 per hectare (46¢ per acre) including photo acquisition, printing and field checking, or $1.85 per hectare (75¢ per acre) when the cost of OCRS training and consultation was included. Even the higher unit cost was one-third that of the field survey method.

In 1982, as an aid to users of the technique, the OCRS published a volume entitled *An Instruction Manual on the Assessment of Regeneration Success by Aerial Survey.*

In 1982/83, weather permitting, photo coverage for the original three districts will be completed, as well as for new areas in the Northwestern Region. Only two scales of photography are planned, 1:15,840 (matching the FRI photo scale) and 1:8,000 (a compromise between 1:9,000 and 1:4,500), in order to increase the area coverage which can be achieved using a two-camera system within the six-week optimal photo season, and to minimize the cost. Refresher courses in the assessment method will be conducted and basic training provided to any district new to the program.

Future plans include further investigation of the use of airborne video recording for regeneration assessment, and research toward the development of a methodology for assessing deciduous regeneration.

The aerial regeneration assessment technique provides the forest manager with a practical means of attaining a comprehensive understanding of regeneration conditions over large areas, parts of which may be virtually inaccessible on the ground. The method also permits a more precise initial stratification of the site than could be achieved without an aerial overview. As a result, a minimum amount of field sampling is required and the efficiency of the field work is increased. Furthermore, although the acquisition of aerial photography is limited to the spring season, the photographic assessment, unlike the field survey, can be continued throughout the year. For these reasons, the methodology represents a significant advance in forest management in Ontario.

AERIAL FOREST SAMPLING

In cooperation with the Forest Resources Group of the Ministry of Natural Resources, the OCRS has for several years conducted a program to develop an aerial photographic method of obtaining the detailed forest sampling data, traditionally obtained by ground sampling, which is required to support the provincial aerial photographic forest inventory system. The proposed methodology is based on large-scale 70mm black and white photography, from which tree species are identified and photogrammetric measurements made of tree dimensions using a stereoplotter.

The Centre acquired a tip-tilt recorder in order to obtain more precise data on flying altitude for better control of the accuracy of tree height measurements. Modifications are being made to the instrument to improve accuracy and response time. Photography was obtained in Gogama District, using the tip/tilt recorder and a foliage-penetrating radar altimeter; this coverage will be evaluated in 1982/83. Work will also continue on the identification of a parameter measurable on the photography from which tree diameters may reliably be calculated when trunks are obscured by crown foliage.

A remote sensing method for forest sampling would be of particular value for areas where ground access is difficult, and would provide a permanent visual record of timber resources.

ASSESSMENT OF FOREST DAMAGE FROM SPRUCE BUDWORM INFESTATION

In cooperation with the Pest Control Section of the Forest Resources Group, Ministry of Natural Resources, the OCRS is in the process of establishing a technique based on colour aerial photography for the assessment of forest damage from spruce budworm infestation.

In 1980/81, the OCRS acquired 70mm colour photography at a scale of 1:7,000 of a budworm infestation in the Temagami area. In 1981/82, 240mm (9'' x 9'') colour coverage at a scale of 1:10,000 was acquired over Elliot Township in the Kirkland Lake District. These sets of photography, combined with the results of studies conducted in previous years, formed the basis for the development of the assessment methodology.

The basic principle of the technique is that the degree of damage caused by spruce budworm to the foliage of individual trees is reflected in the colour of the crown, as seen from an aerial view. A green crown indicates slight damage, if any; a grey crown indicates heavy damage; and a white crown indicates that the tree is dead. Intermediate shades (green-grey, grey-green and grey-white) indicate intermediate levels of damage.

The first step in the assessment procedure is to make a photo mosaic of the study area, usually from FRI photos. The second is to locate stands composed at least 40% of the budworm host species, balsam fir and white spruce, from FRI stand maps. Colour aerial photography at a scale no smaller than 1:10,000 is then acquired, preferably in early summer, to sample cumulative budworm damage in these stands. One-hectare sample plots are randomly located on the photographs using a grid overlay. The distribution of the host species within each sample is assessed, the crown colour of each tree is identified, and the proportion of the sample occupied by trees of each colour is established. From calculations performed using these data, a damage level value is assigned to the sample. The results for all the sample plots in a stand are then used to determine the level of damage that exists within the stand as a whole, on a scale from 1 to 4. The damage classes obtained for all sampled stands are marked on the photo mosaic, to provide a visual summary of forest conditions.

This method of aerial assessment of budworm-caused stand damage will allow the forest manager to direct protective spraying to areas where it will be most useful, to salvage the wood from stands which cannot be saved, and to monitor the progress of the infestation in marginal stands by follow-up photography.

TEST OF METRIC SCALES FOR FOREST RESOURCES INVENTORY PHOTOGRAPHY

In 1979/80, the OCRS began to test the hypothesis that, among scales practical for the metric conversion of the Forest Resources Inventory system, 1:20,000 would be the best choice for Northern Ontario and 1:10,000 for Southern Ontario, from the standpoint of interpretation quality. The test consisted of the independent interpretation by two interpreters of four photo scales for Great Lakes-St. Lawrence forest conditions (1:10,000 1:12,500, 1:15,840 and 1:20,000) and three scales for boreal forest conditions (1:12,500, 1:15,840 and 1:20,000). For each photo set, a compilation map at the scale of 1:15,840 was produced and the total volume of each class calculated. Summaries for each scale and each interpreter of the area coverage of the major classes (water, non-forested areas, productive forest and non-productive forest) were compared.

In 1979/80, the Southern Ontario photography was interpreted. The test was complete in 1980/81 with the interpretation of the Northern Ontario photography.

The results indicated that the scale of 1:20,000 was equally suited for northern and southern forest conditions. It was concluded that, although a larger scale may be required for some very complex forest areas in southern Ontario, for the majority of conditions the slight improvement in interpretation accuracy would not warrant the expense of the 1:10,000 scale. One interesting finding was that the size of stand typed did not decrease on the 1:10,000-scale photography to the extent that had been expected.

The overall conclusion reached was that the training of interpreters and the maintenance of a high standard of photographic quality were the most important factors in ensuring photo interpretation accuracy.

CORRELATION OF PHOTO-INTERPRETED CROWN DENSITY ESTIMATES AND FIELD STOCKING DATA

In cooperation with the Forest Resources Inventory Section of the Ministry of Natural Resources, the OCRS began a study to assess the accuracy of photo-interpreted crown density estimates as an expression of stocking, as compared to actual stocking values obtained by on-site survey, in an effort to identify species or conditions which were particularly difficult to estimate. Four FRI interpreters provided preliminary photo-interpretation data, including crown density estimates and species composition, for approximately 4,000 plots in Southwestern Ontario. Field work at these sites provided information on actual stocking and species composition. The OCRS developed a program in BASIC for the PET microcomputer in order to compare the two sets of data rapidly. It was found that very little correlation existed between the estimates of crown density and the actual stocking data, and that the general tendency was toward underestimating stocking. It was recommended that, where a reasonable relationship is found to exist between the two sets of data over a large number of plots (e.g., over 100), this relationship should be used to correct the preliminary stocking estimates.

The OCRS also compared the photo-interpreted estimates of species composition with the field identification of species, although such a comparison was not part of the original objective of the project. The results demonstrated that the computer program designed for this project could play an important role in the development of photo interpretation skills, by indicating areas where further training in species recognition would be useful.

REMOTE SENSING FOR THE LOCATION OF UNSTABLE MINE ROOF AREAS

In cooperation with the Mining Health and Safety Branch of the Ministry of Labour, the OCRS investigated the usefulness of aerial photography and thermography for the location of subtle bedrock fractures which could cause instability in the roof of a mine.

No major geological faults had previously been identified within the study area. Furthermore, the bedrock was covered by 10 m to 15 m of overburden. The only source of information on bedrock structure, therefore, lay in the topography and drainage characteristics of the surface.

Remote sensing imagery was acquired over the site in early spring, including 1:46,000-scale colour and colour infrared photography, 1:10,000-scale colour infrared photography, nighttime thermography at scales of 1:25,000 and 1:14,000 and daytime thermography at the same scales.

The small-scale photography provided a valuable overview for the recognition of large wet and dry zones and the mapping of regional fracture and drainage patterns. Stereoscopic study of the larger-scale colour infrared photography permitted delineation of the detailed geometry of fracture patterns, minor and intermittent streams and moist or dry depressions. Both scales of thermography were useful in delineating subtle drainage systems and wet depressions not easily recognized on other data, but daytime thermography was superior to nighttime data for this purpose.

When the streams in the area were mapped, they were found to join each other at angles of 70° to 85°. From this rectangular pattern, it was evident that the course of the streams was determined by bedrock fractures. Parts of the site where a number of streams disappeared or converged within a depression, where lineaments intersected the drainage pattern or where many lineaments occurred together, were identified as potential subsidence zones and recommended for examination on geophysical and stratigraphic data, and for on-site and underground observation. Mining engineers in the field subsequently confirmed the accuracy of several of the roof instability areas identified. The remote sensing technique formulated and tested in this project has thus been proven a valuable source of information, both for investigating the safety of existing mines and for planning the location of future mine shafts. As a method of locating fractures in areas covered by a thick layer of overburden, the technique also has potential application to mineral exploration, geological mapping and studies of groundwater resources.

REMOTE SENSING ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF PIPELINE RIVER CROSSINGS

In cooperation with the Environmental Assessment Branch of the Ministry of Environment and two pipeline companies, the OCRS began acquiring and interpreting examples of multispectral photography and thermography which demonstrate the effects of a pipeline river crossing on slope stability, erosion, soil structure and drainage, in areas with different geological and engineering materials. This project will provide knowledge of the environmental effects of pipeline crossings and the processes by which they are produced; and also of the best aerial photographic and thermographic specifications for monitoring these effects.

AERIAL PHOTOGRAPHY IN A HOMICIDE INVESTIGATION

The OCRS was requested by the Ontario Provincial Police in London to acquire and interpret aerial photography of an area in which it was suspected a body had been buried one year previously. It was hoped that a method could be developed for the detection of a grave from visible changes in vegetation produced by differences in soil compaction or drainage or from evidence of a small mound or hollow. Simultaneous colour, colour infrared, black and white and black and white infrared stereoscopic coverage was obtained at a scale of 1:3000, both in spring, when plant growth had just begun, and in summer, when plant growth was well established. Appropriate features which could not be attributed with confidence to some other cause were located and given a priority rating. Although it was found that the film types and scale employed were appropriate for the detection of a body-sized ground disturbance, no results of any OPP investigation at the site were subsequently provided for an evaluation of the technique.

QUANTITATIVE MAPPING OF THE CHLOROPHYLL CONTENT OF LAKE WATER

In 1979/80, the OCRS began to develop a technique based on digitized aerial photography for the quantitative mapping of chlorophyll and suspended sediments in lakes. In 1980/81, four-camera, narrowband aerial photography was taken over near-shore Lake Ontario at Wesleyville. Three reflectance targets provided by the Canada Centre for Remote Sensing (CCRS) were placed in the water before the mission as reference sources for film calibration and the analysis of reflectance levels. The photography was digitized using CCRS facilities. Models of chlorophyll and suspended sediment content developed by MONITEQ Ltd. were to be used for the computer analysis of the digitized photography. Work began on the installation of the MONITEQ software into the OCRS digital image analysis system.

An established method already exists, based on airborne multispectral scanner data, for the quantitative assessment of chlorophyll and suspended sediments in lake water. Aerial photography, however, would be a more accessible source of this information.

AERIAL PHOTOGRAPHIC RESEARCH

The airborne sensing unit of the OCRS continued an ongoing program to develop and improve photo acquisition techniques, in support of the Centre's research and application projects. A procedure was developed for the objective evaluation of the degree of success achieved by aerial photographic missions: a grid was developed to check overlap, and a series of photo samples were compiled for the comparative evaluation of exposure settings. A program of film testing was also conducted. Flights were performed to provide more precise data on the effect of altitude variation on colour infrared photography. The degree of variation between colour infrared emulsion batches was also tested. A number of new films, including Ilford XP1400, Agfa Vario XL and H and W Control film, were tested for exposure latitude and resolution. Airborne experiments were also conducted on the ability of various film/filter combinations to record detail below the surface of waterbodies. The first steps were taken in an investigation of ultraviolet photography and video recording for the assessment of industrial air pollution.

AIRBORNE OPERATION MANUAL

An in-house instruction manual was prepared for operators of the OCRS microcomputer-controlled, 70mm multi-camera aerial photographic system. This manual specifies procedures for the control of exposure interval for a variety of lens focal lengths and flying altitudes, and provides checklists of equipment, operating procedures, flight safety measures and post-flight documentation. The information is not only useful for the quality control of OCRS photo missions, but may provide a valuable source of information to organizations interested in establishing similar photo acquisition systems.

LOW-LIGHT-LEVEL VIEWER

In 1979/80, the OCRS acquired a low-light-level viewer which intensifies available light 40,000 times, as an aid to nighttime flight-line navigation for aerial thermography missions. The Centre also makes this instrument available, on request, to researchers in government, private companies and universities, on the condition that a report is prepared on the testing performed. A significant feature of the instrument is that it can be linked to a 35mm camera or a video camera to record images with the enhanced light.

The Wildlife Branch, the Wildlife Research Branch, and the North-Central regional office of the Ministry of Natural Resources used the viewer with success in the nighttime observation of moose behaviour. The Rabies Research Unit of the Wildlife Research Branch made nighttime observations of foxes, and subsequently purchased their own viewer. The Maple and Lindsay District offices of the Ministry found the viewer and the capability for nighttime photography useful in surveillance and the protection of property within a provincial park. Each of the studies performed assessed the effectiveness of the system under different levels of available light and at different distances from the subject under observation.

AIRBORNE VIDEO RECORDING EXPERIMENTS

The OCRS began to test the potential usefulness of airborne colour video recording from a helicopter for surveys of forest regeneration, forest damage, wild rice beds and agricultural land use. Video recording would offer important advantages over aerial photography. First, the recording medium is much less expensive: the only cost of a colour video recording is $30 for the tape, while long-roll colour film is

more expensive in itself, and also requires processing and printing. The fact that video imagery can be viewed on a TV monitor during the flight improves quality control. In addition, the data can be used immediately, as no processing is required. The combination of helicopter maneuvrability and the video zoom and freeze-frame features provide recording flexibility. The operator of the video camera also has the opportunity to report his observations on the sound track during the flight.

A test conducted over Finch Township to assess the usefulness of video recording as a back-up system to the LANDSAT-based methodology for updating agricultural land use maps provided evidence of the efficiency of the technique. To gather field survey data on agricultural land use across the township (a 16 km^2 area) took five two-person crews one month (approximately 200 man-days). To obtain the same data by airborne video recording took two and one-half days for data acquisition by two persons and four days for transfer of the data to a map by one person (a total of nine man-days).

AERIAL THERMOGRAPHY FOR BUILDING HEAT LOSS ASSESSMENT

The OCRS coordinated the acquisition by Intertech Remote Sensing Ltd. and the Centre's own airborne sensing unit, of winter, nighttime aerial thermography and reference colour aerial photography as the basis for a program of residential energy conservation clinics, known as the HEAT SAVE Program, conducted by the Conservation and Renewable Energy Group of the Ministry of Energy. Clinics were conducted in ten communities (Sault Ste. Marie, Sudbury, Pembroke, Brockville, Belleville, Midland, Orillia, Cobourg, Brantford and St. Thomas) during 1980/81; and in three communities (Thunder Bay, Woodstock and Toronto) during 1981/82. Thermal and photo coverage were acquired for seven additional communities (Cambridge, Owen Sound, Whitchurch/Stouffville, Barrie, North Bay, Ottawa and Toronto West). Thermal coverage alone was obtained for the city of Peterborough. For the clinics, the Centre provided annotated prints of thermography and photography on which residents could locate their homes and examine the thermal behaviour of the buildings. Employees of public utility companies and other staff hired within the community were trained by OCRS in interpreting the imagery.

The program is scheduled to continue in 1982/83, with the acquisition of coverage for twelve additional centres.

Aerial thermography is playing an important role in promoting the need for energy conservation measures on the level of the individual Ontario household.

BIBLIOGRAPHY ON THERMOGRAPHY APPLICATIONS TO FORESTRY

A comprehensive literature search was conducted through two computerized data banks (the RESORS system and the CAN/OLE data bank) to provide the basis for preparation of an annotated bibliography of studies relevant to applications of thermography in forestry. The references were classified into three subject areas – forest damage studies; forest mapping, classification and monitoring; and environmental studies. Sources of information on the comparison of thermal sensing and imaging instruments on the market were included, as well as an introduction to satellite thermal sensing.

This bibliography provides a summary of the state-of-the-art of thermography in forest management, as the basis for future research.

MONITORING OF LEACHATE OUTBREAKS IN LANDFILL SITES

The OCRS collaborated with M.M. Dillon Ltd. and Gartner-Lee Associates Ltd. in a survey of possible leachate outbreaks at six landfill sites for the Ministry of the Environment. Intertech Remote Sensing Ltd. acquired aerial thermography over the sites in late winter, early spring and late fall. Global Remote Sensing Ltd. obtained supporting aerial photographic coverage. The OCRS interpreted the thermography, identifying leachate point sources and accumulations; Gartner-Lee Associates Ltd. interpreted the photography; and M.M. Dillon was responsible for obtaining background information on the landfills and integrating all three sets of data into a report on the condition of the sites.

The OCRS obtained additional thermography over the Ridge Landfill Site near Blenheim for the Southwestern Regional Office of the Ministry of the Environment, and examined the imagery for evidence of leachate outbreak. Ministry of Environment personnel obtained reference photography and correlated the thermography interpretation results with ground data. No occurrences of leachate outbreak were discovered from the thermography; this result was confirmed by ground checking. Potential areas of leachate outbreak, however, were identified.

AERIAL THERMOGRAPHIC DETECTION OF INACTIVE MINE SITES

In cooperation with the Inactive Mines Coordinating Committee of the Ministry of Natural Resources, the OCRS conducted tests to determine whether aerial themography could provide a means of locating potentially hazardous abandoned mine shafts and trenches. During the winter of 1981, aerial thermography and stereoscopic photography were acquired at several scales over abandoned or inactive mine sites near Cobalt and Bancroft. The mine sites were detected on the aerial thermography, but other thermal anomalies also appeared on the imagery which might have been suspected to be mine sites, if the locations had not already been known. A second test was conducted over known mine sites in the vicinity of Wawa in the summer of 1981. Field measurements of air temperatures within and outside mine shafts were made in order to correlate the extent of thermal variation with its representation on the aerial thermography.

FIGURE 1(a)
Dr. S. Pala, Chief Scientist of the OCRS, demonstrates the processing elements of the digital image analysis system: two sets of image display hardware and the host computer.

FIGURE 1(b)
Image analysis in progress at the interactive image display terminal of the first workstation.

FIGURE 1(c)
The newly-acquired second computer workstation (right). A digitizing table integrated with the image analysis system (left) permits polygon features on existing maps to be combined with digital analysis results.

FIGURE 2
The Applicon computerized colour plotter prints hard-copy maps from the results of digital image analysis.

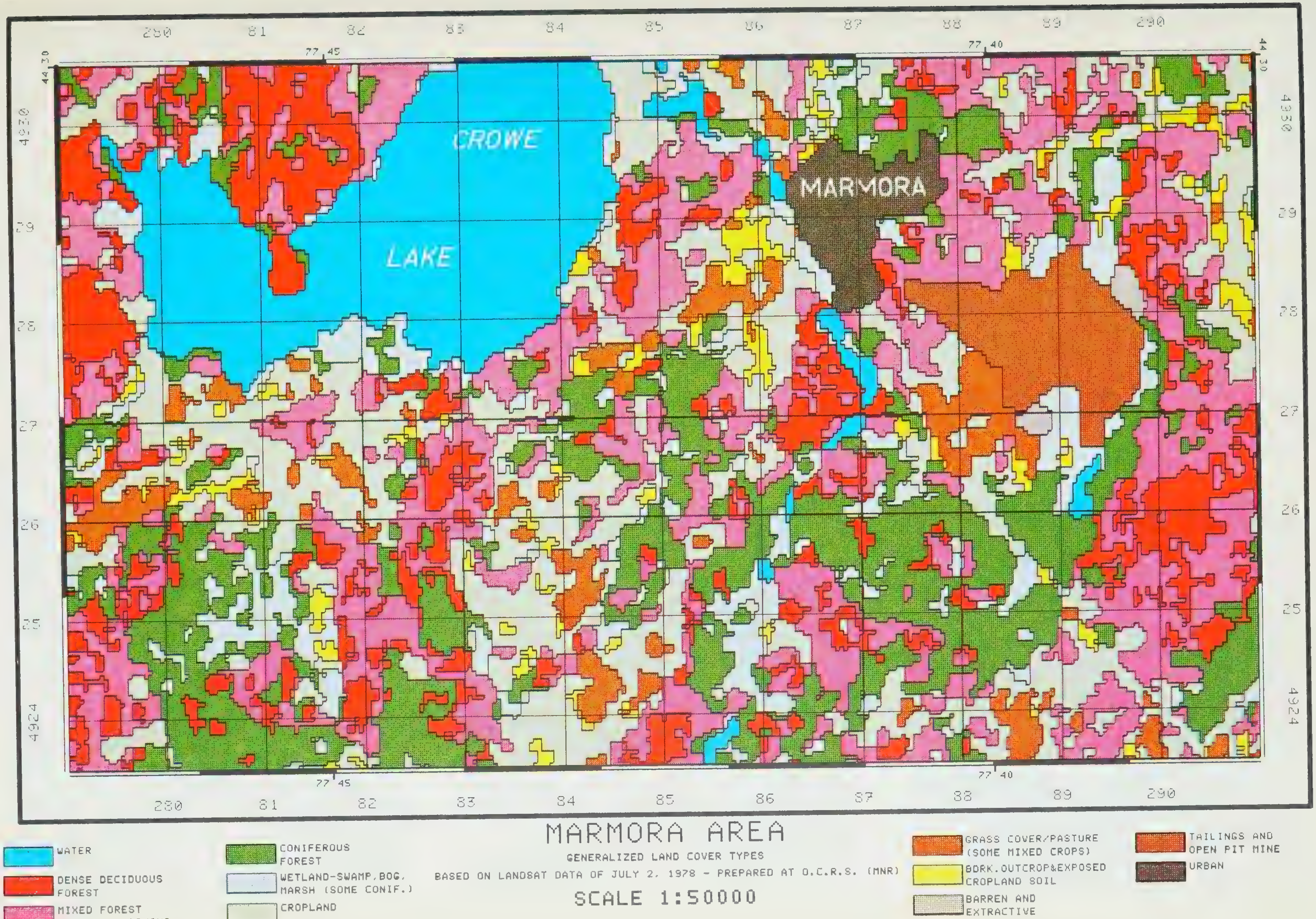

FIGURE 3
Sample land use map derived from the digital analysis of LANDSAT data and printed by the Applicon computerized colour plotter.

FIGURE 4
The OCRS Navajo Chieftain aircraft.

FIGURE 5
Interior of OCRS aircraft outfitted for acquisition of aerial photography and thermography, with a Daedalus dual-channel infrared linescanner (foreground) and a multiple-camera mount with 70 mm cameras in place (centre). Both systems are controlled at the instrument rack in the left background, for convenient acquisition of simultaneous coverage.

FIGURE 6
The Daedalus thermal infrared processing unit. Thermal infrared data is stored on magnetic tape. The data can be manipulated and monitored simultaneously to provide hard-copy imagery suitable to project requirements.

It was found that mine sites could not be positively identified on the thermography, nor could structures within the sites be distinguished, even when the sites were not obscured by foliage and when the temperature differential measured in the field was pronounced (10° to 15°C). The conclusion was drawn that, as known mine sites could not be successfully located on the aerial thermography, it would not be possible to conduct a survey for unknown sites using this technique.

DIGITAL THERMAL PLUME MAPPING

For this study, airborne thermography in digital form was obtained offshore of the Bruce Generating Station on Lake Huron. For the first time, the data was geometrically corrected to map sheets of the Ontario Basic Mapping Program. One map was produced on the Applicon mapping system with a picture element (pixel) size of 3 metres at a scale of 1:10,000. A subset of this test area was resampled at a scale of 1:2,500 to produce a pixel size of 1 metre. The maps produced with the Applicon system from an analysis of the geometrically-corrected digital thermography provide extremely detailed information on the distribution of hot water effluent from the Bruce "A" Nuclear Generating Station.

RADAR INTERPRETATION OF WETLANDS

Four-channel synthetic aperture radar (SAR) imagery was acquired by the Canada Centre for Remote Sensing of a site near Peterborough selected by the OCRS for the assessment of SAR data for geological applications. In 1980/81, the value of this data for identifying types of wetland was examined. Black and white airphotos at a scale of 1:10,000 and field investigations provided support data for the SAR interpretation. SAR imagery from the SEASAT satellite, which provided a ground resolution of approximately 25 m^2, was also examined for its response over the wetland sites. It was found that X-band SAR was useful for detecting low vegetation in standing water (bushes and low reeds), and for distinguishing between wetlands with little open water surface and those with larger open water areas. L-band SAR provided the same information for areas with higher vegetation (standing, leaning or fallen bare tree trunks). The same difference between the two bands was obtained from the airborne SAR and the SEASAT SAR data. It was concluded that SAR data could provide a means of distinguishing wetland types by their vegetation cover and degree of open water surface, factors which combined to determine the nature of the radar response.

PARTICIPATION IN THE PLANNING OF A CANADIAN RADAR SATELLITE

The launch of a Canadian radar satellite known as RADARSAT is planned for the late 1980's, primarily for the monitoring of coastlines and sea ice as an aid to navigation, but also for the analysis of geology and vegetation. Two OCRS scientists are members of both the Renewable Resources Group and the Non-Renewable Resources Group of the national RADARSAT experiment committee. This organization is responsible for organizing and coordinating research projects to determine the most useful sensor parameters for the satellite.

UNDERWATER MAPPING EXPERIMENT

In collaboration with MONITEQ Ltd., the OCRS produced several experimental maps using the Applicon system, based on bathymetric and bottom-type mapping models developed by that company. The primary source of information for this study was airborne multispectral scanner data obtained for the project by the Canada Centre for Remote Sensing.

DEVELOPMENTS IN THERMAL IMAGE PROCESSING

Recent experiments in the processing of aerial thermography have increased the capability for extracting specific data from existing thermal imagery.

Two separate thermal signals can now be combined; for example, level-sliced data can be superimposed on analogue data to achieve a detailed enhancement of temperature differences. This technique has been particularly useful in the presentation of the thermal signatures of building roof-tops for an appreciation of heat loss.

In the relative processing mode, a particularly interesting portion of a thermal signal can be emphasized through signal level manipulation which can enhance the contrast between the temperature of a feature of interest and its thermal background.

TECHNOLOGY TRANSFER

The program of technology transfer designed and introduced to government organizations, the private sector and universities and colleges in Ontario in 1979/80 was put into practice on a broad scale over the period 1980-1982. A high level of interest was encountered in all three sectors: 70 different Ontario Government organizations, of which 48 were offices of the Ministry of Natural Resources, participated in the program, as well as two municipal government bodies, 45 private companies, 16 university departments and three colleges. Seven federal agencies and five organizations from other provinces also took part. The following is a summary of the Centre's technology transfer activities over the two-year period.

SERVICES PROVIDED TO THE ONTARIO GOVERNMENT

The OCRS provided consultation and/or assistance, free of charge, to personnel from the following Ontario Government agencies:

- Ministry of Natural Resources:
  - Ontario Geological Survey
  - Mineral Resources Branch
  - Land Management Branch
  - Parks and Recreational Areas Branch
  - Fisheries Branch
  - Fire Management Branch
  - Regional Offices:
    - Northeastern (Sudbury)
    - Eastern (Kemptville)
    - Algonquin (Huntsville)
    - Southwestern (London)
    - Central (Richmond Hill)
  - District Offices:
    - Moosonee
    - Kenora
    - Cochrane
    - Fort Frances
    - Gogama
    - Chapleau
    - Ignace
    - Parry Sound
    - Cambridge
  - Cataraqui Conservation Authority
  - South Lake Simcoe Conservation Authority
  - Leslie Frost Natural Resources Centre
  - Niagara Escarpment Commission
- Ministry of the Environment
- Ministry of Agriculture and Food
- Ministry of Government Services
- Ministry of Labour
- Ministry of Transportation and Communications
- Ministry of Municipal Affairs and Housing
- Ontario Hydro
- Royal Ontario Museum
- Ontario Provincial Police
- Ontario Energy Corporation
- Cabinet Committee on Resources Development

Services were also provided to the Regional Municipality of Peel.

The range of subjects on which consultation or assistance was provided is indicated by the following examples:

- survey of remote sensing applications to parks planning and management
- availability of imagery for specific sites and purposes
- equipment and operating procedures for small-format aerial photography
- acquisition and use of colour infrared photography
- remote sensing techniques for hydro line route and tower access route selection
- integration of remote sensing into fisheries management programs
- survey of remote sensing techniques for water quality monitoring
- analysis of LANDSAT data for geology
- introduction to the aerial photographic technique for forest regeneration assessment
- test of video camera survey technique for agricultural land use updates
- information on status of forest cutting activities in Northern Ontario from LANDSAT imagery
- capabilities of LANDSAT data and video recording for peat bog assessment
- application of LANDSAT imagery to the study of river sedimentation processes
- aquatic weed detection on aerial photography
- aerial thermography for the detection of spring locations
- potential application of aerial thermography for the mapping of near-surface aggregates
- use of aerial thermography for the mapping of fracture patterns
- use of portable thermal imagers for the detection of heat loss from buildings
- use of LANDSAT imagery for the study of ice formation and break-up in lakes
- use of LANDSAT imagery for the planning of field expeditions in Northern Ontario
- use of LANDSAT imagery enhancements for the study of archeological sites

SERVICES PROVIDED TO GOVERNMENT ORGANIZATIONS BEYOND ONTARIO

Applicon mapping software developed by the OCRS was provided to the federal Canada Centre for Remote Sensing, on request, and has been fully installed within the CCRS Applicon colour plotting system so that the federal organization may produce maps from the digital analysis of LANDSAT data for its users.

OCRS provided the following consultation to federal government organizations:

Geological Survey of Canada: identification of plutons from enhanced LANDSAT data

Canada Centre for Mineral and Energy Technology: digital analysis of LANDSAT data for peat resource surveys

Department of Indian and Northern Affairs: use of thermography for aggregate exploration
National Energy Board: use of large-scale aerial photography for monitoring pipeline construction
Department of Agriculture: instrumentation and field techniques for obtaining reflectance data on soils
Atmospheric Environment Service: the use of LANDSAT data for a delineation of broad land-cover types

The services available under the technology transfer program were described in depth to members of the Policy Directorate of Environment Canada and the Intergovernmental Committee on Urban and Regional Research.

OCRS staff served as an information source for the following government agencies in other provinces:

Nova Scotia Department of Lands and Forests: regarding the aerial forest regeneration assessment technique and other remote sensing applications to forestry
Environmental Assessment Division and Alberta Remote Sensing Center: regarding the OCRS digital analysis and computerized mapping systems
British Columbia Ministry of Forests: regarding the aerial forest regeneration assessment method
B.C. Research: Collaboration to complete a digital LANDSAT classification for an area in south-eastern British Columbia

SERVICES PROVIDED TO THE PRIVATE SECTOR

Consultation from one-half day to two days in length was provided free of charge to the following private companies:

Abitibi Pulp and Paper Co. Ltd.
Acres Consulting Services Ltd.
Agradave - Montreal
Air, Earth and Oceans Ltd.
Alberty, Fullerits, Dickson & Associates
Algoma Steel Corporation Ltd.
Arbex Forest Development
J.D. Barnes Ltd.
Beak Consultants Ltd.
Canadian Gypsum
Canadian Occidental Petroleum Ltd.
Chapman, Connerty and Associates
James Dobbin Associates Ltd.
Domtar Forest Products
Ducks Unlimited
Ecologistics Ltd.
The Environmental Applications Group Ltd.
Bruce Graham, Consulting Geologist
Gulf Canada Resources Inc.
Gulf Minerals Canada Ltd.
Hatch Associates Ltd.
Heathwood Engineering Associates Ltd.
Ralph Hedlin Associates
Hunter and Associates Ltd.
INCO Metals
Infrascan Sales Ltd.
Interprovincial Pipeline
Master Chart Visual Systems
Ernie McLaren Construction Ltd.
Moniteq Ltd.
Montreal Engineering Co. Ltd.
M.P.H. Consulting Ltd.
Pegasus Earth Corporation
Prairie Agri Photo Ltd.
Questor Surveys Ltd.
Reconnaissance Air Ltd.
Reinhard & Guttenberg Metallgesellschaft
Robinson, Merritt & deVries
C.D. Schultz & Co. Ltd.
Selco Mining Corporation
Spruce Falls Power and Paper
TransCanada Pipeline
Union Gas
Urbanprobe Associates Ltd.
van Ginkel Associates
Cy Wilde Environmental and Forest Resources Services

The range of subjects on which companies consulted the OCRS was as follows:

- general overview of remote sensing data types and their capabilities
- survey of OCRS programs
- image availability for specific areas and subjects
- video cameras and recorders for aerial sensing
- aerial photographic survey methodology for forest regeneration assessment
- survey of remote sensing applications to geological mapping
- applications of LANDSAT imagery in mineral exploration
- remote sensing techniques for structural geology mapping, particularly applications of thermography and photography to the detection of bedrock fractures
- remote sensing applications to the detection of groundwater discharge and recharge areas
- radar imagery interpretation
- aerial photography and thermography for the study of environmental impact of a pipeline and for the selection of pipeline river crossing sites
- application of LANDSAT data to biomass mapping
- mapping of areas of burned forest on LANDSAT imagery
- survey of computer image enhancement techniques
- digital analysis of LANDSAT data for land use mapping
- digital analysis of LANDSAT data in forestry
- analysis of LANDSAT data for James Bay Lowland investigations
- inventory of peat resources using LANDSAT data
- surficial geology mapping north of latitude 50°N
- testing and evaluation of a new thermal imaging video camera
- use of aerial and on-site thermography for the assessment of heat loss from buildings
- LANDSAT analysis supplemented by video recording for the mapping of agricultural land use

Demonstrations were given of the Centre's digital image analysis and computerized mapping systems and analogue electronic image enhancement system. In addition, and invited lecture was presented to the Algoma Steel Company in Sault Ste. Marie.

SERVICES PROVIDED TO OCRS BY THE PRIVATE SECTOR

The private sector in Ontario provided the following services and products in support of OCRS applied research programs over the period 1980-82:

Nature of Service/Product	*Dollar Value*
Image acquisition	224,000
Photo processing/printing	167,000
Photo materials and equipment	182,000
Lease, outfitting and operation of aircraft	357,000
Imagery	53,000
Digital analysis equipment	193,000
Digital analysis supplies	23,000
Digital system maintenance	39,000
Software development	123,000
Video recording supplies and services	14,000
Total of major payments to the private sector for products and services, 1980-82:	$1,375,000.

This sum represents approximately 49% of the total gross operating budget of the Centre over the two-year period.

SERVICES PROVIDED BY OCRS TO UNIVERSITIES

Consultation and assistance were provided free of charge to faculty members and graduate and senior undergraduate students from the following universities:

Brock University, Department of Geography
University of Guelph: University School of Rural Planning and Development, Department of Land Resource Science
Lakehead University, Department of Forestry
Laurentian University, School of Engineering
McMaster University: Communications Research Laboratory, Department of Geography
Queen's University, Department of Geography
Ryerson Polytechnical Institute
University of Toronto: Department of Civil Engineering, Faculty of Forestry
University of Waterloo, Department of Geography
York University, Department of Geography
University of Manitoba, Department of Geography
Nova Scotia Land Survey Institute

Subjects on which information was sought included the following:

- procedures of digital image analysis and computer map production
- digital analysis of LANDSAT data for land cover mapping
- surficial geology mapping of Northern Ontario using aerial photography and LANDSAT imagery
- information on SEASAT imaging systems
- selection of aerial thermography examples and information for course planning
- interpretation of aerial thermography for the location of groundwater springs
- use of aerial thermography in lake temperature studies
- selection of material use in an atlas of Ontario for primary schools
- acquisition and use of colour infrared aerial photography
- operation and applications of laser fluorosensor
- use of analogue electronic image analyzer in soil porosity analysis
- applications of remote sensing to gravel pit reclamation and landfill site programs
- instruction in the processing of aerial thermography

The following workshops were given at the OCRS to groups of 15 to 30 students, at the request of the teaching staff of universities and colleges:

Algonquin College of Applied Arts and Technology
- survey of remote sensing applications

Brock University, Department of Geography
- introduction to practical applications of remote sensing

Georgian College of Applied Arts and Technology
- workshop on remote sensing applications to geology and forestry
- introduction to practical applications in remote sensing

University of Guelph, Department of Land Resource Science
- introduction to practical applications of remote sensing with a workshop on selected application areas

Lakehead University, Faculty of Forestry
- introduction to practical applications of remote sensing (2 seminars)

McMaster University, Department of Geography
- computer analysis of LANDSAT data for land use mapping

Sir Sandford Fleming College of Applied Arts and Technology
- introduction to practical applications of remote sensing

University of Toronto, Department of Civil Engineering
- introduction to practical applications of remote sensing

University of Toronto, Faculty of Forestry
- introduction to radar sensing
- survey of remote sensing applications to landscape architecture
- LANDSAT applications to forestry (two workshops)

University of Toronto, Department of Geography
- introduction to practical applications of remote sensing for senior undergraduates

University of Waterloo, Department of Geography
- introduction to practical applications of remote sensing
- LANDSAT digital analysis for land use and forestry
- special seminar for graduate students

OCRS staff gave the following lectures at universities, at the invitation of professors:

University of Guelph, Department of Land Resource Science
- survey of remote sensing applications

McMaster University, Department of Geography
- interpretation of radar imagery: lecture and workshop (2 occasions)

Queen's University, Department of Geography
- survey of remote sensing applications in geography

Ryerson Polytechnical Institute
- lecture on radar theory and image interpretation; preparation of material for follow-up labs
- lecture to senior survey engineering students

University of Toronto, Computer Science Department
- digital image enhancement and classification techniques

University of Toronto, Faculty of Forestry and Landscape Architecture
- remote sensing applications in forestry (three lectures)
- remote sensing for geotechnical and geological engineering
- photo interpretation of tree species (four seminars)

Trent University, Department of Geography
- survey of remote sensing applications

University of Waterloo, Department of Environmental Studies
- radar imagery interpretation
- mapping of surficial geology and wetlands in the Hudson Bay Lowland

University of Waterloo, Department of Geography
- classification of wetlands of the Hudson Bay Lowland
- digital LANDSAT image analysis techniques
- applications of remote sensing to terrain and land use mapping

Thesis supervision and assistance were provided to university students, as follows:

Brock University, Department of Geography
- supervision of two internship students

University of Guelph, Department of Civil Engineering
- M.Sc. thesis on groundwater and aquifer detection

McMaster University, Department of Geography
- M.Sc. thesis on the digital analysis of LANDSAT data for land use
- M.Sc. thesis on the digital analysis of LANDSAT data for geology

University of Toronto, Faculty of Forestry
- doctoral thesis on large-scale photo sampling
- M.Sc. thesis on radar in geology
- M.Sc. thesis on LANDSAT data analysis for boreal forest typing
- M.Sc. thesis on soil moisture monitoring by aerial thermography
- M.Sc. thesis on applications of remote sensing of forest engineering

University of Toronto, Department of Geography
- M.Sc. thesis in sampling design for densitometric measurements

University of Waterloo, Department of Geography
- M.Sc. thesis on the application of LANDSAT data to land use studies
- senior honours essay on thermography for spring detection
- photogrammetric guidance and preparation of computer program for measurement of simulated snow loads

At the secondary school level, OCRS scientists gave presentations to geography teachers of the Scarborough and East York Boards of Education.

THE COMMITTEE ON ADVANCED REMOTE SENSING EDUCATION AND RESEARCH

In 1981, the OCRS initiated the formation of a committee to advance remote sensing education and research at Ontario post-secondary educational institutions. The committee is composed of 33 professors from 14 universities and 4 colleges, as well as one representative of the OCRS.

The organization elected a Steering Committee comprised of three members serving for three years and three members serving for two years. The Chief Scientist of the OCRS was elected chairman of the Steering Committee. The Steering Committee determined that its first task was to compile an inventory of training and research resources and programs at the educational institutions of the province.

The Terms of Reference adopted by the organization are as follows:

1. To maintain, on behalf of the universities and colleges of the Province of Ontario, an inventory of courses offered in remote sensing in the Province, instructors, curricula, written teaching materials, and equipment on hand and proposed for acquisition.
2. To provide, on request, advice to a post-secondary institution or an individual instructor on curricula, methods of instruction and teaching materials in remote sensing.
3. To identify and request specialists to teach specific courses, as required.
4. To act, on request, as a source of informed comment on programs in remote sensing at the graduate level.
5. To identify topics for which teaching materials are needed, to be prepared by the OCRS and other members of the Committee, with the cooperation of the Steering Committee.
6. To identify the types of workshops to be organized at OCRS for remote sensing instructors.
7. To evaluate, on request, and, if appropriate, support applications to government agencies

and other granting bodies by universities and colleges for funds to finance the purchase of major equipment and the performance of research.

8. To advise government ministries and departments of the need for research and development of sensors, techniques of remote sensing data analysis and applications of remote sensing technology, as necessary.
9. To use the OARS and CCRS newsletters to inform the remote sensing community regarding the activities of the Committee on Advanced Remote Education and Research.
10. To seek funding for publication of most important Ontario research projects.
11. To appoint sub-committees as necessary.
12. To arrange one meeting per year for the Committee of the Whole, at which the Steering Committee and sub-committees will report on developments in teaching and research at post-secondary institutions and the Ontario Centre for Remote Sensing, and future plans will be discussed.

TRAINING COURSES

OCRS conducted seventeen formal training seminars over the period 1980-82, primarily for Ontario Government staff, but with attendance from other sectors as well, including private industry and universities in Ontario, federal government organizations, government bodies in other provinces, and international agencies (Figure 7). With the exception of the course for supplementary aerial photography operators, attendance was limited to 10 for maximum personal attention.

Remote Sensing Seminar for Professional Staff

A seminar designed to give resource management-related professionals hands-on experience with practical applications of a range of remote sensing data types. The 15 participants who attended the two seminars which were conducted during 1980-82 represented the following organizations:

Ontario Government:

Ministry of Natural Resources
- Hearst District Office
- Nipigon District Office
- North Central Regional Office (Thunder Bay)
- Leslie M. Frost Natural Resources Centre (Dorset)
- Niagara Escarpment Commission

Private Companies:
- Acres Consulting Services Ltd.
- Questor Surveys Ltd.

Universities:
- University of Toronto, Department of Geography
- Trent University, Department of Geography

Other Provinces:
- B.C. Research
- Resource Planning Branch, Government of the Yukon Territory

International:
- Institute of Geodesy, Budapest, Hungary
- Uranium Geology Research Institute, Beijing, People's Republic of China

Remote Sensing Seminar for Managers

A seminar designed to inform managerial staff of the capabilities of a range of remote sensing data types and to introduce practical applications already established. Twenty-seven participants attended three seminars, among them the following managers:

Ontario Government:

Ministry of Natural Resources
- Regional Offices
  - Algonquin (Huntsville)
    - Deputy Regional Director
    - Forest Protection Coordinator
    - Regional Engineer
  - Eastern (Kemptville)
    - Regional Lands Coordinator
    - Regional Wildlife Biologist
  - North Central (Thunder Bay)
    - Fire Operations Supervisor
    - Regional Forestry Specialist
  - Northeastern (Sudbury)
    - Regional Mining Lands Administrator
    - Regional Planner
- District Offices
  - Lindsay
    - Lands and Mines Supervisor
  - Algonquin Park
    - Park Operations Manager
  - North Bay
    - Lands Supervisor
    - Forest Management Supervisor
  - Espanola
    - District Planner
  - Chapleau
    - Forest Management Supervisor
    - two Unit Foresters
- Outdoor Recreation Group
  - Executive Coordinator
- Ontario Geological Survey
  - Manager, Geoservices
- Leslie M. Frost Natural Resources Centre
  - Acting Resources Planning and Management Superintendent

Private Companies:
- Northway-Gestalt Corporation: General Manager

Federal Government:
- Indian and Northern Affairs: Chief, Aggregate Division, Indian Minerals (East) Directorate

Specialty Remote Sensing Seminar on Land Use Applications

A seminar designed to give land use planners and other users of land use data practical knowledge of the application of LANDSAT data, aerial thermography and airborne radar data to the identification of types of land use. Participants receive hands-on experience in visual, analogue electronic and digital image analysis techniques, and instruction in the use of the OCRS computerized mapping system.

The first land use seminar was conducted in 1981, and was attended by nine participants from the following Ontario Government organizations:

Ministry of Natural Resources:
- Central Region (Richmond Hill)
- Algonquin Region (Huntsville)
- Moosonee District (2 participants)
- Niagara Escarpment Commission
- Land Use Coordination Branch
- Aviation and Fire Management Centre

Ministry of Agriculture and Food:
- Economics Branch

Ministry of the Environment:
- Northeastern Regional Office (Sudbury)

Specialty Remote Sensing Seminar on Forestry Applications

A seminar designed to give foresters practical knowledge of the application of LANDSAT data, aerial thermography and airborne radar data to the survey and assessment of forest resources. Participants receive hands-on experience in visual, analogue electronic and digital image analysis techniques, and instruction in the use of the OCRS computerized mapping system.

The first forestry seminar, conducted in 1981, was attended by five participants from the following Ontario Government organizations:

Ministry of Natural Resources:
- Timber Sales Branch
- Algonquin Forestry Authority
- Hearst District
- Leslie M. Frost Natural Resources Centre

Ministry of the Environment
- Air Resources Branch

Specialty Remote Sensing Seminar on Geological Applications

A seminar designed to give geologists practical knowledge of the application of LANDSAT data, aerial thermography and airborne radar data to the identification of features significant in the mapping of structural and surficial geology and in mineral exploration. Participants receive hands-on experience in visual image interpretation and in a range of digital image analysis techniques. Instruction is provided in the use of the OCRS computerized mapping system.

The first geological seminar was conducted in 1981, and was attended by 12 participants from the following Ontario Government offices and private companies:

- Ontario Geological Survey (3 participants)
- Northern Region (Cochrane) (2 participants)
- Selco Incorporated (4 participants)
- Umex Incorporated
- Placer Development Ltd.
- INCO Metals Company

Remote Sensing and Photo Interpretation for Forestry Applications (with emphasis on boreal forest conditions)

This course was conducted five times during the two-year period, and was attended by 47 participants from the following government organizations and private companies:

Government:

Ministry of Natural Resources
- District Offices
  - Ignace
  - Kenora
  - Fort Frances
  - Dryden
  - Red Lake
  - Sioux Lookout
  - Terrace Bay
  - Geraldton
  - Thunder Bay
  - Atikokan
  - Kapuskasing
  - Kirkland Lake
  - Cochrane
  - Gogama
  - Timmins
  - Chapleau
  - Wawa
- Regional Office
  - North Central Region (Thunder Bay)
- Main Office
  - Forest Resources Inventory

Ontario Hydro, Route and Site Selection Division

Private companies:
- Acres Consulting Services Ltd.
- American Can of Canada Ltd.
- Beak Consultants Ltd.
- Boise Cascade Canada Ltd.
- Domtar Forest Products

Remote Sensing and Photo Interpretation for Forestry Applications (with emphasis on Great Lakes-St. Lawrence forest conditions)

A total of 31 participants from the following organizations attended three courses:

Government:

Ministry of Natural Resources
- District Offices
  - Pembroke
  - Minden
  - Parry Sound
  - Bracebridge
  - Algonquin Park
  - Lanark
  - Brockville
  - Huronia
  - Niagara
  - Owen Sound
  - North Bay
  - Wawa
  - Espanola
  - Sault Ste. Marie

Sudbury
Blind River

Regional Office
Southwestern Region (London)

Metropolitan Toronto and Region Conservation Authority

Private Companies:

Acres Consulting Services Ltd.
Domtar Forest Products

In addition to the longer training courses, a half-day seminar was conducted for foresters-in-training of the Ministry of Natural Resources on remote sensing applications in forestry. OCRS staff also participated in three other Ontario Government training programs: the new Liskeard Soils Course (September, 1981), the Sudbury Soils Courses (fall, 1980 and 1981) and the Forest Soils Mapping Course held in New Liskeard in May of 1980.

FIGURE 7

A scene from an OCRS training seminar: General Remote Sensing Seminar for Professionals, October, 1981. Left side of table: participants from Questor Surveys Ltd.; Resource Planning Branch, Government of the Yukon Territory; Trent University. Right side of table: participants from the Uranium Geology Research Institute, Beijing, People's Republic of China; Hearst District and Niagara Escarpment Commission, Ministry of Natural Resources; Institute of Geodesy, Budapest, Hungary. Instructor: Dr. S. Pala.

EXPANSION OF TECHNOLOGY TRANSFER TO THE PRIVATE SECTOR, 1982-86

The OCRS submitted a proposal to the Board of Industrial Leadership and Development (BILD) for funding to conduct an expanded program of training in digital image analysis and computer map production for private companies in Ontario. The objective of the program is to establish the capability in the private sector for operational digital analysis services, to meet the needs of a growing provincial, national and international market. The expertise gained by the participating companies is expected to result in a significant increase in the volume of remote sensing-related business in the province and to significantly increase the amount of remote sensing-related employment. It is also expected to give Ontario companies the potential to be world leaders in this new field.

The Centre will provide interested companies with intensive hands-on training on its computer system, and will assist them in the performance of their first operational projects.

The BILD Committee granted $600,000 to the Centre in 1982/83 to prepare for this technology transfer program. The Committee is considering allocation of a total of $3 million to the program over the period 1982 to 1986.

INTERNATIONAL ACTIVITIES

Under the Canada-West Germany Scientific and Technical Exchange Program, the OCRS played host to Mr. R. Kessler and Dr. W. Endlicher of the University of Freiburg, West Germany. Mr. Kessler received intensive training over a two-week period in the interpretation of airborne radar imagery, in preparation for participation in a major European radar sensing program. He also prepared a paper jointly with an OCRS staff member for presentation at the 1981 conference of the American Society of Photogrammetry. With the assistance of OCRS staff, Dr. Endlicher learned to perform digital LANDSAT image analysis and to carry out computerized map production on the OCRS systems, and also conducted research into imagery of the HCMM (Heat Capacity Mapping Mission) satellite and into airborne radar data. Dr. Endlicher returned to the Centre in the fall of 1981 before embarking for a teaching position at the University of Concepcion, Chile.

During Dr. Endlicher's first visit, the Centre also hosted Mr. Liu Xianbing of the Uranium Research Institute of Beijing, People's Republic of China, and Mr. Peter Stephens of the Aokautere Science Centre, Government of New Zealand. Both of these scientists were taking part in information exchange programs with the federal government, Mr. Liu at the Geological Survey of Canada and Mr. Stephens at the Canada

Centre for Remote Sensing. The OCRS organized an in-house workshop at which each visitor gave a presentation on his personal involvement in remote sensing both in his home country and in Canada. The workshop also included a demonstration of OCRS-developed remote sensing applications and ongoing research programs.

Professor Dr. W. Weischet, Dean of the Faculty of Geography, University of Freiburg, visited the Centre in order to prepare a joint paper with Dr. S. Pala, Chief Scientist of the OCRS, for presentation at the International Symposium on the Hudson Bay-James Bay Lowland held at the University of Guelph in April, 1981.

Under the Canada-Germany Scientific and Technical Exchange Program, Dr. S. Pala, the Chief Scientist of the OCRS, conducted seminars in multidisciplinary applications of LANDSAT data and in the principles and applications of airborne radar imagery, at the University of Freiburg in January, 1982.

Mr. Gyorgy Buttner of the Remote Sensing Department, Institute of Geodesy, Budapest, Hungary, worked with OCRS scientists for two months in the fall of 1982 to gain experience in the digital analysis of LANDSAT data for land use mapping, and familiarity with the computerized map production system.

An OCRS staff member visited the Environmental Photographic Interpretation Centre of the U.S. Environmental Protection Agency in Warrenton, Virginia, for an exchange of information on the use of remote sensing techniques in detecting industrial waste pollution.

As part of a program organized and conducted by the Canada Centre for Remote Sensing, the OCRS hosted three scientists from Thailand for a demonstration of remote sensing applications.

The Centre provided consultation to visiting scientists from the following agencies:

National Aeronautics and Space Administration, Goddard Space Flight Institute, Greenbelt, Maryland, U.S.A.

United States Gypsum Company, Chicago, U.S.A.

Officina Nacional de Evaluacion de Recursos Naturales, Peru

International Institute for Aerial Survey and Earth Science, Enschede, The Netherlands

Institut fur Meteorologie, Frei Universitat Berlin, Federal Republic of Germany

Department of Earth Sciences, The Open University, England

Remote Sensing Applications Branch, Department of Environment and Planning, South Australia

The subjects on which consultation was given included the following:

- the practical application of LANDSAT data through digital analysis and computerized map production
- mapping of subsurface fracture patterns using aerial thermography and photography
- tectonic mapping of the Canadian Shield from LANDSAT data
- demonstrations of operational remote sensing applications

The opportunities of the OCRS for international exchange were increased in 1980/81 by the election of the Centre to membership in the European Association of Remote Sensing Laboratories (EARSeL), and the appointment of an OCRS scientist as the only Canadian member of the Education and Training Working Group of EARSeL.

PROPOSED INTERNATIONAL SUMMER SCHOOL

The Education and Training Committee of EARSeL accepted an OCRS proposal to conduct a three-week summer course in 1983 for 20 scientists from European remote sensing laboratories, in application-oriented digital image analysis and computerized map production. Representatives from both EARSeL and the European Space Agency (ESA) have expressed the intention of providing a financial contribution to the course. The OCRS made application to the Scientific Affairs Division of NATO for the additional funding required.

The course is designed to provide those European laboratories which are in the best position to use digital remote sensing, with the opportunity to develop the required expertise. Although relatively few individuals can be accommodated by this form of hands-on education, the scientists selected to attend will represent organizations able to disseminate the new knowledge. The participants will also be introduced to the capabilities of Ontario industry in digital analysis hardware and software production and in other areas of remote sensing, such as airborne image acquisition.

BOOKLET

The following booklet is distributed by the OCRS on request:

Pala, S. The Comprehensive Program of Remote Sensing Technology Transfer at the OCRS: A Unique Approach.

MANUAL

The following manual was produced by the OCRS with funding from the Forest Resources Group of the Ministry of Natural Resources.

Goba, N., S. Pala and J. Narraway. *An Instruction Manual on the Assessment of Regeneration Success by Aerial Survey.* Ontario Centre for Remote Sensing, Ministry of Natural Resources, January, 1982.

This publication is available at a cost of $10 per copy from the Ontario Government Bookstore, 880 Bay Street, 1st Floor, Toronto; or by mail from Publications Services, 5th Floor, 880 Bay Street, Toronto, Ontario M7A 1N8.

PROJECT REPORTS

With the approval of the project sponsor, project reports may be perused at OCRS headquarters; however, it is OCRS policy not to distribute copies of them. The following reports were produced during the period 1980-1982:

A Documentation of Work Procedures Necessary for Effective Use of the OCRS Airborne Imaging System

Evaluation of Remote Sensing for the Detection of Abandoned or Inactive Mine Shafts, Adits and Trenches

An Evaluation of Remote Sensing Data for Mine Safety Analysis: A Case Study

Infrared Radiometric Survey over the Pickering Nuclear Generating Station

Investigation of Remote Sensing Techniques for Wild Rice Inventory

Remote Sensing Investigation for Ontario Provincial Police

The Ridge Landfill Site Thermal Imagery: Technical Data and Image Presentation

Scale Test: Evaluation of Photographic Scales for the Purpose of Forest Resources Inventory in Ontario

Spruce Budworm Damage Assessment from Aerial Photography and Alternative Remote Sensing Technology

Thermography and Forestry: A Selective, Annotated Bibliography on the State of the Art

Training and Quality Control for FRI Interpreters: Stocking-Density Curves Developed from the 1981 FRI Field Plots.

DISPLAYS

Civil Servants' Solar Energy Club Meeting, Toronto, November, 1980.

Meeting of the Ontario Foresters' Association, Toronto, February, 1981.

International Symposium on the Hudson Bay-James Bay Lowland, Guelph, April, 1981.

Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba, September, 1981.

Meeting of the Ontario Association of Remote Sensing, Ontario Science Centre, Toronto, November, 1981.

Workshop on Applications of Remote Sensing in Ecological Land Surveys, Arnprior, January, 1982.

Peatland Inventory Methodology Workshop, Ottawa, Ontario, March, 1982.

75th Anniversary Display, Faculty of Forestry, University of Toronto, March, 1982.

Sportsman's Show, Faculty of Forestry Display, Toronto, March, 1982.

PUBLISHED PAPERS, 1980-82

Boissonneau, A., 1981. Canadian Initiatives in Wetland Inventory. *Proceedings,* Ontario Wetlands Conference, The Federation of Ontario Naturalists and Department of Applied Geography, Ryerson Polytechnical Institute, Toronto, Ontario.

Ellis, T.J. and J. Quinn, 1980. The Evolution of the Community Thermography Information Programme in Ontario. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980.

Ellis, T.J. and E.M. Senese, 1981. Remote Sensing in Pollution Abatement. *Proceedings,* 28th Ontario Industrial Waste Conference, Toronto, June, 1981.

Jano, A. and S. Pala, 1981. LANDSAT-Based Forest Mapping in Ontario North of Latitude 52° North. *Proceedings,* Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba, September, 1981.

Jano, A., 1981. Practical Applications of Remote Sensing for Forest Pest Damage Appraisal. Presented paper, In-House Remote Sensing Seminar, Canadian Forestry Service, Edmonton, Alberta.

Lawrence, G.R. and A. Banner, 1980. The Application of Thermography for Locating Potential Frost Pockets in Forest Cutovers. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia.

Pala, S., R. Mussakowski and E. Wedler, 1980. Applicability of Airborne SAR Data to Geological Mapping. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980.

Pala, S., E. Wedler and A. Jano, 1980. Coniferous Regeneration Assessment on SAR Imagery. Prepared for the SURSAT-SAR Project Office, Energy, Mines and Resources Canada.

Pala, S., R. Mussakowski and E. Wedler, 1980. SEASAT-SAR Data Evaluation for Structural and Surficial Geology. *Proceedings,* XIV Congress of the International Society for Photogrammetry, Hamburg, West Germany, 1980.

Pala, S., 1980. A Working Concept of Remote Sensing Technology Transfer. Fourteenth International Symposium on Remote Sensing of Environment, San Juan, Costa Rica, April, 1980.

Pala, S., T.J. Ellis and D.B. White, 1981. Operational Land Cover Type Mapping in Ontario by LANDSAT-Based Digital Analysis and Map Production. *Proceedings,* Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba, September, 1981.

Pala, S., 1981. Radar Sensing: Promising New Tool for Exploration. *The Northern Miner,* Vol. 67, No. 6, April 16, 1981, p. B17.

Pala, S. and W. Weischet, 1981. Toward a Physiographic Analysis of the Hudson Bay-James Bay Lowland. *Proceedings,* Symposium on Scientific Studies on the Hudson Bay-James Bay Lowland. *Le Naturaliste Canadien* (in press).

Pala, S. and A. Boissonneau, 1981. Wetland Classification Maps for the Hudson Bay Lowland. *Proceedings,* Symposium on Scientific Studies on the Hudson/James Bay Lowland. *Le Naturaliste Canadien* (in press).

Singhroy, V. and J.F. Wightman, 1981. Bank Erosion and Flood Plain Studies of the Annapolis River: An Application of Remote Sensing Data. *Proceedings,* Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba, September, 1981.

Singhroy, V. and M. Duggin, 1981. Measurements of the Characteristic Reflective Spectra of Surficial Deposits. *Proceedings,* Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba.

Watts, J., 1980. The Use of Remote Sensing for Archeological Research in a Woodland Environment. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980.

Wedler, E., 1980. Quantitative Chlorophyll Mapping Using Ultra-Narrow Band Airborne Photography. Presented Paper, Specialty Conference on Civil Engineering Applications of Remote Sensing, Madison, Wiconsin, August, 1980.

Wedler, E., S. Pala and A. Jano, 1980. Synthetic-Aperture Radar in Forest Regeneration Success Survey. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980.

Wedler, E. and R. Kessler, 1981. Interpretation of Vegetative Cover in Wetlands Using Four-Channel SAR Imagery. Presented Paper, Conference of the American Congress of Surveying and Mapping and the American Society of Photogrammetry, Washington, D.C., February, 1981.

Zsilinszky, V.G., 1980. A Proposal for the Reorganization of the Canadian Advisory Committee on Remote Sensing. *1979 Report,* The Canadian Advisory Committee on Remote Sensing.

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UNPUBLISHED PRESENTATIONS

Boissonneau, A.N. The Classification of Wetlands. Ministry of Natural Resources Senior Planners' Meeting, Toronto, June, 1980.

Boissonneau, A.N. Wetlands of the Hudson Bay Lowlands. Toronto Field Naturalists Botany Group, Toronto, November, 1981.

Boissonneau, A.N. and D. White. Use of LANDSAT CCT's and Applicon Colour Plotter to Provide Maps of Land Use Data. Canada Committee on Ecological (Bio-Physical) Land Classification, Arnprior, January, 1982.

Boissonneau, A.N. The Hudson Bay Lowlands. Brodie Club, Toronto, February, 1982.

Pala, S. Digital Output Products. Meeting of the Ontario Association of Remote Sensing, Toronto, April, 1980.

Pala, S. Land Cover Mapping Using Digital Analysis of LANDSAT Data. Meeting of the Ontario Association of Remote Sensing, Toronto, November, 1980.

Pala, S. Space Technology in Land Use Monitoring. Remote Sensing Conference of the Ontario Society for Environmental Management, Toronto, November, 1981.

Singhroy, V. Evaluation of Remote Sensing Data for Mine Safety Analysis. Remote Sensing Conference of the Ontario Society for Environmental Management, Toronto, November, 1981.

Zsilinszky, V.G. Presentation of the Chairman of the Interprovincial/territorial Advisory Subcommittee of the Canadian Advisory Committee on Remote Sensing, to the Inter-Agency Committee on Remote Sensing, Ottawa, September, 1981. (Mr. F. Hegyi, representative to the Canadian Advisory Committee on Remote Sensing from British Columbia, presented the address on the Chairman's behalf.)

Zsilinszky, V.G. Keynote Address to the Remote Sensing Conference of the Ontario Society for Environmental Management, Toronto, November, 1981.

Zsilinszky, V.G. A Provincial Perspective on the Use of Remote Sensing Technology. Address to the Annual Meeting, Canadian Advisory Committee on Remote Sensing, Arnprior, March, 1982.

CURRENT PARTICIPATION OF OCRS STAFF ON COMMITTEES AND IN ASSOCIATIONS

Representation for Ontario on the Canadian Advisory Committee on Remote Sensing

Membership, Executive of the Canadian Advisory Committee on Remote Sensing

Chairmanship of the Interprovincial/territorial Advisory Subcommittee of the Canadian Advisory Committee on Remote Sensing

Membership in the Engineering Working Group of the Canadian Advisory Committee on Remote Sensing

Membership in the Forestry, Wildlife and Wildlands Working Group of the Canadian Advisory Committee on Remote Sensing

Membership in the Geoscience Working Group of the Canadian Advisory Committe on Remote Sensing

Membership and extensive involvement in the Ontario Association of Remote Sensing

Membership, Ontario Ministry of Natural Resources, Forum on Science-Oriented Management Systems

Vice-Chairmanship of the Canadian Remote Sensing Society

Membership in the RADARSAT Committee for Renewable Resources

Membership in the RADARSAT Committee for Non-Renewable Resources

Membership in the RADARSAT Technical Committee on Secondary Sensors

Membership in the Canadian Government Specifications Board Committee on Thermography

Membership in the Canadian Institute of Forestry

Membership in the Geological Association of Canada

Membership in the Ontario Professional Foresters' Association

Membership in the Ontario Forestry Association

Membership in the Applications Working Group of the Canada Committee on Ecological (Biophysical) Land Classification

Representation for Ontario on the Canadian Committee on Ecological (Biophysical) Land Classification

Representation for Ontario on the National Wetlands Working Group of the Canada Committee on Ecological (Biophysical) Land Classification

Membership on the Advisory Committee of the Sir Sandford Fleming College Natural Resources Program

Representation on the Steering Committee of the Geographical Inter-University Resource Management Seminars

Membership, Ontario Ministry of the Environment Remote Sensing Users Committee

Membership in the Committee on Advanced Remote Sensing Education and Research

Chairmanship of the Steering Committee of the Committee on Advanced Remote Sensing Education and Research

Membership, Remote Sensing Study Group, North American Forestry Commission

Chairmanship of the Remote Sensing Study Group of the International Union of Forest Research Organizations

Membership in the Editorial Board of *Photogrammetria*, official journal of the International Society for Photogrammetry

Membership in the European Association of Remote Sensing Laboratories

Membership in the Education and Training Working Group of the European Association of Remote Sensing Laboratories

CONFERENCE PARTICIPATION

Niagara Falls Meeting, Canadian Committee on Ecology and Land Classification, March, 1980.

Canadian Government Specifications Board Standards Committee on Thermography, Ottawa, April, 1980.

Fourteenth International Symposium on Remote Sensing of Environment, San Jose, Costa Rica, April, 1980.

Meeting, Geoscience Working Group of the Canadian Advisory Committee on Remote Sensing, Ottawa, May, 1980.

Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980.

Meeting, National Wetlands Working Group, Canadian Committee on Ecological (Bio-Physical) Land Classification, Inuvik, N.W.T., August, 1980.

Thermosense III - Thermal Infrared Sensing Applied to Energy Conservation in Building Envelopes, Minneapolis, Minnesota, September, 1980.

American Congress of Surveying and Mapping/American Society of Photogrammetry (ACSM-ASP) Fall Technical Meeting, Niagara Falls, October, 1980.

Remote Sensing for Resource Management Conference of the Soil Conservation Society of America, Kansas City, Missouri, October, 1980.

Meeting, Northern Region Spruce Budworm Working Committee, Timmins, November, 1980.

Conference, American Congress of Surveying and Mapping/American Society of Photogrammetry (ACSM/ASP), Washington, D.C., February, 1981.

Meeting, Ontario Forestry Association, Toronto, February, 1981.

RADARSAT for Non-Renewable Resource Meeting, Ottawa, February, 1981.

RADARSAT for Renewable Resource Meetings, Ottawa, February and April, 1981.

Colloquium on the Application of the Next Generation of Earth Resource Satellites, Montreal, March, 1981.

Symposium on Scientific Studies on Hudson/James Bay, Guelph, April, 1981.

Canadian Forestry Service In-House Seminar on the Uses of Remote Sensing in Forest Pest Damage Appraisal, Edmonton, Alberta, May, 1981.

European Association of Remote Sensing Laboratories Symposium on the Application of Remote Sensing Data on the Continental Shelf and the Fifth General Assembly of EARSeL, Voss, Norway, May, 1981.

Fifteenth International Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, May, 1981.

28th Ontario Industrial Waste Conference, Toronto, June, 1981.

Seventh International Symposium on Machine Processing of Remotely-Sensed Data, West Lafayette, Indiana, June, 1981.

American Society of Civil Engineers/American Society of Photogrammetry Specialty Conference on Civil Engineering Applications of Remote Sensing, Madison, Wisconsin, August, 1981.

Remote Sensing Study Group, North American Forestry Commission, Washington, D.C., August, 1981.

Fourth Meeting of the National Wetlands Working Group of the Canada Committee on Ecological (Bio-Physical) Land Classification, Prince Rupert, B.C., August, 1981.

Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba, September, 1981.

XVII World Congress of the International Union of Forest Research Organizations, Kyoto, Japan, September, 1981.

Ministry of Environment Regional Conference, North Bay, September, 1981.

Cities Conference, Ministry of Municipal Affairs and Housing, Toronto, October, 1981.

Peat Symposium, Thunder Bay, October, 1981.

Meeting, Canadian Remote Sensing Society, Ottawa, November, 1981.

Annual Northern Ontario Forest Pest Review, Sault Ste. Marie, November, 1981.

Conference on Remote Sensing for Environmental Management, Ontario Society for Environmental Management/Ontario Association of Remote Sensing/ Canadian Remote Sensing Society, Toronto, November, 1981.

Eastern Spruce Budworm Conference, Bangor, Maine, January, 1982.

Workshop on Applications of Remote Sensing in Ecological Land Surveys in Canada, Arnprior, January, 1982.

Meetings of the Ministry of the Environment Remote Sensing Users' Committee, February 8 and March 2, 1982.

Peat Inventory Methodology Workshop, Ottawa, March, 1982.

Annual Meetings, Canadian Advisory Committee for Remote Sensing, April, 1980; April, 1981; April, 1982.

Meetings of the Interprovincial/Territorial Advisory Sub-Committee to the Canadian Advisory Committee on Remote Sensing, September, 1980, January, 1981, March, 1981, September, 1981, February, 1982.

Meetings of the Executive of the Canadian Advisory Committee on Remote Sensing, June, 1981, November, 1981, April, 1982.

All meetings of the Ontario Association of Remote Sensing

PUBLICATIONS OF THE ONTARIO CENTRE FOR REMOTE SENSING: CUMULATIVE LIST

Boissonneau, A. and J.K. Jeglum, 1975. A Regional Level of Wetlands Mapping for the Northern Clay Section of Ontario. *Proceedings,* Third Canadian Symposium on Remote Sensing, Edmonton, Alberta, p. 349-358.

Boissonneau, A., 1975. Use of LANDSAT Imagery to Map Burns and Estimate Timber Damage. *Proceedings*, Workshop on Canadian Forest Inventory Methods, Dorset, Ontario, p. 79-82.

Boissonneau, A., 1976. Research and Surveys for Biophysical Mapping in Ontario. *Proceedings,* First Meeting of Canada Committee on Ecological (Biophysical) Land Classification, p. 33-38.

Boissonneau, A. and S. Pala, 1978. An Ecological Classification Project for the Ontario Portion of the Hudson Bay-James Bay Region. *Proceedings,* Second Meeting, Canada Committee on Ecological (Biophysical) Land Classification, Victoria, B.C., p. 65-72.

Boissonneau, A., 1981. Canadian Initiatives in Wetland Inventory. *Proceedings,* Ontario Wetlands Conference, The Federation of Ontario Naturalists, Toronto, Ontario (in press).

Ellis, T.J. and J. Quinn, 1980. The Evolution of the Community Thermography Information Programme in Ontario. *Proceedings,* Sixth Canadian Symposium on Remote Sensing, Halifax, Nova Scotia, May, 1980, p. 109-110.

Ellis, T.J. and E.M. Senese, 1981. Remote Sensing in Pollution Abatement. *Proceedings,* 28th Ontario Industrial Waste Conference, Toronto, June, 1981, p. 245-252.

Goba, N., S. Pala and J. Narraway, 1982. *An Instruction Manual on the Assessment of Regeneration Success by Aerial Survey.* Ontario Centre for Remote Sensing, Ministry of Natural Resources, January, 1982, 57 pp.

Graham, C., 1975. Remote Sensing - An Aid to Pipeline and Hydro Tower Construction in Agricultural Areas. *Proceedings,* Third Canadian Symposium on Remote Sensing, Edmonton, Alberta, p. 383-392.

Jano, A., 1975. Timber Volume Estimate with LANDSAT-1 Imagery, *Proceedings,* Workshop on Canadian Forest Inventory Methods, Dorset, Ontario, p. 83-86.

Jano, A., 1979. Choice of Scale for FRI Photography. *Proceedings,* Remote Sensing Symposium of the Canada-Ontario Joint Forest Research Committee, Toronto, Ontario, p. 101-114.

Jano, A., 1979. Large-Scale Photography for Forest Inventory Problems and Limitations. *Proceedings,* Workshop on Practical Applications of Remote Sensing to Timber Inventory, Edmonton, Alberta, p. 52-57.

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Jano, A.P., 1981. Practical Applications of Remote Sensing for Forest Pest Damage Appraisal. *Proceedings,* In-House Remote Sensing Seminar, Canadian Forestry Service, Edmonton, Alberta, p. 30-39.

Lawrence, G. and C. Graham, 1975. Remote Sensing Applied to Algal Problems in Lakes. *Proceedings,* Third Canadian Symposium on Remote Sensing, Edmonton, Alberta, p. 309-314.

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Lawrence G., T. Ellis and P. Smith, 1978. The Value of Qualitative Interpretation of Aerial Thermography in Residential Heat Loss Studies. *Proceedings,* Fifth Canadian Symposium on Remote Sensing, Victoria, B.C., p. 244-250.

Lawrence, G., 1979. Some Applications of Thermography to Forest Management. *Proceedings,* Remote Sensing Symposium of the Canada-Ontario Joint Forest Research Committee, Toronto, Ontario, p. 137-146.

Lawrence, G.R. and A. Banner, 1980. The Application of Thermography for Locating Potential Frost Pockets in Forest Cutovers. *Proceedings,* 6th Canadian Symposium on Remote Sensing, Halifax, N.S., p. 369-376.

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Pala, S. and A. Boissonneau, 1981. Wetland Classification Maps for the Hudson Bay Lowland. *Proceedings,* Symposium on Scientific Studies on the Hudson/James Bay. *Le Naturaliste Canadien* (in press).

Singhroy, V. and J.F. Wightman, 1981. Bank Erosion and Flood Plain Studies of the Annapolis River: An Application of Remote Sensing Data. *Proceedings,* 7th Canadian Symposium on Remote Sensing, Winnipeg, Manitoba.

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Zsilinszky, V.G., A. Giannelia and M. Rafelson, 1979. A Review of the Supplementary Aerial Photography Program of the Ontario Ministry of Natural Resources. *Proceedings,* Remote Sensing Symposium of the Canada-Ontario Joint Forest Research Committee, Toronto, Ontario, p. 115-124.

Zsilinszky, V.G., 1979. A User's Notes on Remote Sensing Application. *Proceedings,* International Symposium on Remote Sensing for Natural Resources, Moscow, Idaho, p. 1430-1450.

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